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O. Chanute

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Journal of the
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VOL. VI. FEBRUARY, 1901 NO. 1.

CVIII.

THE IMPROVEMENT OF THE CHICAGO RIVER.

Addresses at the Annual Dinner of the Western Society of Engineers at the Grand Pacific Hotel January 8, 1901.

CAPT. R. W. HUNT, CHAIRMAN.

Gentlemen and Fellow Members of the Western Society: As one year passes after another in my life I find that the occasion in each to which I can look back with perhaps as much pleasure as any other is the one when I am certain to meet you of this society, which is so dear to our hearts, and whose prosperity we can, I think, claim as belonging to ourselves, the success attending it has come through our efforts, and so that when we annually come together to kind of shake hands with each other, we can at the same time shake hands with ourselves.

Now, gentlemen, we are fortunate tonight in having so many distinguished gentlemen, who are not members of our society, to talk to us. In the past, perhaps, our family has indulged a good deal in family talk, but tonight we call upon our friends and neighbors to join us in this council, and I know that you will extend to them, one and all, that warm welcome which you know so well how to give.

And it seems quite proper that the subject under discussion should be the Chicago River improvements, if I am to act as toastmaster. Perhaps some of you may recall an incident that I told you some years ago, at the time that we were all trying to have the World's Fair located in Chicago. It happened that a distinguished gentleman of the city of New York spoke, in my presence, of the presumption of Chicago in assuming that it was a proper place for the World's Fair, and he said: "Why, my dear sir, this is an international proposition which is being discussed, and it should properly be located on a great seaport." "Well," I said, "Sir, does not that apply to Chicago, for, if you will consult statistics, the commerce of our great and mighty lakes exceeds any foreign commerce that you can present, and certainly exceeds the commerce of any one coast seaport." "That is all very well, of course; that is very fine, but you must remember that Chicago is nothing but a fresh water port," said he. And I replied: "My dear sir, have you ever stood at the mouth of the Chicago River?" [Applause.] Fortunately we had the fair, for that argument could not prevail now.

Now, this great change in our port has been brought about by the efforts of distinguished men, by the efforts of far-seeing men, by the expenditure of an immense amount of money, and it seems only right that the discussion on that subject being the topic tonight, that it should be opened by the man who inaugurated the movement, who engineered the enterprise which has led to the present improvement and points to the further improvement of the Chicago River. Gentlemen, I present to you Mr. L. E. Cooley. [Applause.]

MR. L. E. COOLEY.

The issue before the public is whether we shall go forward or whether we shall stop. To stop will be disastrous to the city of Chicago. We are "up against the real thing" now. The United States has said that we could use the Chicago River, provided we did not exceed a current of a mile and a quarter an hour, and that the use of the same was not to be to the detriment of commerce. That it has been to the detriment of commerce is universally conceded, and to continue to use the river as it has been used during the past year is simply to invite a revocation of the permit by the Secretary of War, without any legal or equitable right of protest. On the other hand, not to furnish the volume of water required by the State law is liable to invoke the redress which the law provides. The law requires not less than 340,000 cubic feet of water per minute to be carried out of the Sanitary District on the present basis of population for 1,700,000 people, and further requires that the volume shall be increased 20,000 cubic feet for every 100,000 additional inhabitants. This must be furnished constantly and without interruption. Furthermore, in case the general government shall undertake the improvement of the Des Plaines and Illinois Rivers, as contemplated by State law and as contemplated by the surveys which have been ordered in the House Bill just reported to Congress, for not less than fourteen feet of water between Chicago and St. Louis, then the Sanitary District is required to complete said channel with a capacity of not less than 600,000 cubic feet per minute—the full capacity required by law—within one year after said work is undertaken. The object of this is manifest. The State, in granting Chicago the privilege of sewage disposal in the Illinois Valley, provided, and it is intended to provide, for a waterway through the State of Illinois, and this is a part of the contract between Chicago and the Illinois Valley which cannot be set aside.

The remedy under the State law is that any citizen or any municipality may file a complaint with the Attorney General of the State, and it is made his duty forthwith to file any information in the nature of a mandamus in the Supreme Court, and the Sanitary District is authorized to levy an emergency tax for the purpose of carrying out any findings of said court. So it will be seen that sticking our heads in the sands and refusing to see the situation in its true light is to constitute a virtual receivership of the Supreme Court, with the power to levy taxes on this community to carry out the work without any regard to the will of its citizens.

The third proposition is that Chicago has already suffered very greatly in its commercial development on account of an inadequate river. In view of the recent deepening of the channels about the Great Lakes, this river would have been inadequate in any event and without regard to its use as a means of conveying water to the Sanitary Canal. Without such use, however, a comparatively moderate development of the stream would have met the immediate emergencies of commerce. We may say, therefore, generally, that the Chicago River has been injured and large expenditures necessitated, on the commercial side, on account of the flow of water through the same, and that said flow of water must absolutely be reduced and provided for in some other way, or else the river must be enlarged to such dimensions as will be sufficient to answer both the purposes of navigation and its purposes as the main waterway of the Sanitary District.

We have every right to assume, and this is a certainty of the situation, that when it shall go out to the world that Chicago has ceased to make efforts to remedy this question, then the Secretary of War will reduce the flow of water in the interest of navigation; and, on the other hand, should he do so, the Illinois Valley will insist upon its rights to have a full flow of water under the law; so that inaction in this matter places Chicago between the devil and the deep sea.

The question of what shall be the remedy is not so easily answered. It is apparent to every citizen that there should be a broad and comprehensive plan—a policy, if you please—to which all expenditures may be directed, so that eventually there shall be produced a complete and satisfactory solution of all the problems involved. This may take many years and require a large amount of money; but there are certain features that will be of immediate utility and are most pressing, and it is not wise or necessary to contemplate expenditures faster than the community can reasonably afford.

It will occur to everyone that there are certain duties devolving upon the general government, and it seems that past efforts have not been wisely directed or the general government would be even now making large expenditures upon our river in conjunction with the city and Sanitary District. It is apparent to everyone that the city has duties in the premises in connection with the tunnels and the bridges, that these are municipal functions and that the general government cannot undertake to enter upon a radical improvement until such time as the city, which owns and is responsible for these constructions, has changed them or made provision for a change in conformity with the predetermined plan. It is apparent, also, that there have been unfortunate contests with the State in regard to the Illinois and Michigan Canal, and that the State, as the sovereign and supreme guardian of the interests of all the people, as well as in its interest through said Illinois and Michigan Canal, has a duty in the premises.

There are questions, also, of broad concern on the health side, which require the consideration of the legal city authorities and of the State Board of Health. It is apparent that before any great results can be obtained, these agencies must be enlisted in co-operation upon some well determined plan. So the first duty is to fix upon some programme by which all these agencies may be brought together. It is proposed that the Sanitary District shall constitute a special committee of three engineers and two lawyers, who are familiar with the questions to be solved, so that they may rapidly crystalize a general project and line of action. It is proposed to associate with such committee, in a consulting capacity, official representatives of the United States, of the city of Chicago, of the State of Illinois, and of the Sanitary District, so that all these agencies may at once acquiesce in some plan of co-operation. It is assumed that the report of such a committee will define the relative responsibilities and field of action of these several agencies, and that when such report has been made, all citizens and all who may be interested will at once secure such legislation by the State and by the city and by the federal government as may be necessary to produce the final result.

As to what such a committee so constituted is liable to determine we are unable to forecast. It is certain, however, that the Sanitary District has responsibilities which the lawyers can clearly define when the sanitary and engineering features are developed. It is certain that the duties and responsibilities of the city of Chicago may be easily set forth, and it will be only a question whether the money to discharge these responsibilities shall be raised through the agency of the city or the Sanitary District, and the results will be practically the same to the people. What the duties of the United States are in the premises is not so easy to determine. It is quite certain that the United States cannot be asked to remedy conditions that are produced solely by the city of

Chicago and the Sanitary District, and that their obligations in the premises must be first provided for. The United States has practically adopted the policy of not expending money on interior harbor improvements beyond the provision of a harbor entrance, and that the ground on which such improvements must be asked for in the city of Chicago is that they constitute part of a waterway channel between the Great Lakes and the Mississippi River and the Gulf of Mexico, in which the entire country is vitally interested. So it will be seen that the waterway policy, running through and under the law, is of vital local concern, aside from the specific benefits of such waterway to the city of Chicago, and aside from the financial relief which the Sanitary District will obtain in averting the claims for overflowed lands throughout the Illinois Valley, which the State law sets aside in case the United States will undertake the improvement of the Illinois River. In any event, the fact of such joint consideration by all the agencies that are interested will be to clearly define the situation and the relative responsibility of all the agencies.

As to how soon this can be done, and whether it can be done in time for legislation during the present session of the General Assembly of Illinois, is purely a question of personality. There are men in this community who are thoroughly competent to determine and present a wise solution of these matters within 60 days; and it is also possible to appoint a committee that will easily take 600 days to do the same thing. The question is "up to" the Sanitary District, and according as they may act in the matter will the future of this question define itself.

The Chairman—Gentlemen, as Mr. Cooley so aptly illustrated the importance of the work by quoting from commercial statistics, we all appreciate that without commercial reasons the improvement of the Chicago River would never have taken place, and its further improvement and the further extension of the waterway to the west and south could not and would not be made.

Therefore, I think that it is only proper, at this point, that we should have the commercial side stated, and I would ask the gentleman whose commercial interests are at least as large as anybody's in Chicago, in relation to the Chicago River, to address us on the subject. Will Mr. P. B. Weare say something?

ADDRESS OF MR. P. B. WEARE.

Mr. President and Gentlemen: I feel very highly honored that I should be requested to make some remarks pertaining to the commerce of the Chicago River, the importance of which you are considering.

I am here because the Chicago River is here. That is why I came to this town some forty years ago. I have been fortunate in being able to place myself on the river in a business position — to handle and transfer property there that is tributary and largely has been the means of building up your city — the grain business.

Of course, we have all suffered in the last quarter of a century from the inconvenience of the bridges, etc., but we have all borne it because of the commerce of the city. Through such men as the gentlemen who have just finished speaking and yourselves, engineers, propositions have come before the people of this city and have been accepted, and our river has been improved to the degree in which you see it today. But you have just commenced, and in most all work when you commence it you sometimes do some damage and injury until you get it fully organized and smoothly working. That is the condition of the Chicago River today. In order to get through you have attacked, unintentionally I think, the commerce. And this has made the question a serious problem.

I suppose, from the plan as outlined by the gentleman who has just finished speaking, that when the act making the Drainage Canal was passed, the proposition that is now up to the present trustees was considered. The figures show it. Whether they thought, with us, that it was going to drive trade away from Chicago, I don't know. But the facts are here before you, that if you obey the drainage district law you break the law of the United States. The law of the United States is the law that the men who are interested in the commerce of Chicago, or the Chicago River, considered when they invested their money in the industries that now line its banks. It is impossible to carry on the commerce of the Chicago River in competition with modern methods of doing business with the current in the river as it is and as necessary to carry out the law. Now this is our position, and cannot be avoided; there is no compromise. It has been suggested by very good men that we go to Springfield and rectify that mistake, so that Chicago won't have to ask for the amount of water that is necessary to be put through this river, to supply every 100,000 people who inhabit the Drainage District with the proper dilution of its sewage. If we made a mistake and were "held up" when the law was passed, I don't think we had better plead the baby act. I think we had better carry out the law. I think so, because I think the city needs 340,000 cubic feet of water a minute through the river. But if you carry out the law, or even two-thirds of it, then we have no commercial navigation in the river. It is not necessary to dam up this river, it is not necessary to put these bridges in the river in order to drive commerce away from here. Modern commerce follows wherever they can do the business the cheapest.

A modern vessel that carries 225,000 bushels of grain cannot come into the Chicago River except at a cost that requires her owners to discriminate against this harbor from 1-16 to ⅛ of a cent a bushel, and I can say to you gentlemen here that 1-32 of a cent a bushel will drive all the grain trade away from Chicago inside of five years.

Now, you gentlemen will wonder why this matter has not come up sooner, why it is that the people on the Chicago River did not make more of a protest before this. There was no harbor for grain except Chicago no harbor nearer than Milwaukee—offering grain shipments, where boats could be rapidly loaded and where full cargoes could be had and were always to be had, until, to be exact, the past three years. Milwaukee grain had been diverted from there, and it came here, and consequently until a short time ago vessels could not go there. They could not get sufficient business there. In the last three years there has been built about—I cannot say exactly, but I should think possibly 10,000,000 of bushels of elevator capacity at South Chicago. All the larger vessels will go to those houses and get their grain at from 1-16 to ⅛ of a cent per bushel less than if they come to Chicago—that is, the modern 225,000 bushel ship. The old-fashioned obsolete ships will come into this market as cheap as before. The reason of that is the current in this river, more than it is the bridges, more than it is the tunnels. You can't handle those large boats except with two expensive tugs. The current in the river is of such a nature that you can't do it, and when you put 225,000 cubic feet of water through this river, which has been the highest current which has been put through it while navigation was active here, it makes it very expensive and very dangerous to take those large boats down the South Branch any distance below Madison street.

Now last week, the Drainage Board very kindly put through 322,000 cubic feet of water per minute, and they have been asked to shut it off, for the reason that it is injuring property at many points on the river. The ice and the swift water are wearing the docks away, and there has been no time in the last week that one could take, with two tugs, a 16,000 bushel old-fashioned sailing vessel from Sixteenth street to Rush street bridge without very great danger, and the owners could not get any insurance if they wished to. The Drainage Trustees have not put through the river the whole amount of water the law requires. They only claimed last week to put through 322,000 cubic feet, but the law today, with the present population, requires 340,000 cubic feet. They don't dare to put that amount through.

This is the subject that is before you engineers, and you are to bring forward any plans that you have, and place them before the board of officers who are elected, and who, I believe, are competent to take up this subject and treat it. There seems to be a desire on the part of the Drainage Board that where such a large undertaking is going to be done as the proper improvement of the Chicago River, that it should go before the people. Now you gentlemen have great influence. What you say goes a long way with the average taxpayer, and it is the average taxpayer's approbation that I believe the Drainage Board would be glad to have on their undertakings. The average man in Chicago has not realized what was going on in the river, he did not know that elevators were being built at South Chicago, he did not know that elevators were being built at Manitowoc. Elevators have been built at those points in the last two years that have taken away from this city in the last year 20,000,000 bushels of grain received from the territory of Southern Iowa, Kansas and Nebraska. Why did it go there? For the reason that the towage in that harbor is practically nothing compared with ours; there is no danger of a vessel being wrecked there, and they can go there for ⅛ of a cent a bushel less than in this river. South Chicago has the same rate as Manitowoc; Green Bay has the same rate. And the rate from all the western territory tributary to this city is just the same as to those points mentioned. Green Bay has another elevator there that did a big business last year. Milwaukee and Waukegan are getting larger proportions this year than we are. And as to South Chicago, that should not be anything more than an overflow of business from here. Many of you will have it said to you that South Chicago is the proper place for the commerce of Chicago, and that that is the port of Chicago. Now, gentlemen, you know better than that; anybody who tells you that, as far as Chicago is concerned, is mistaken. If all the grain that has formerly come here goes to South Chicago, and all the coal that has formerly come here, and all the lumber that has formerly come here, and the iron that has formerly come here, goes to South Chicago, a large portion of the commerce of Chicago will be done at South Chicago, and Chicago will be merely a way station between the rails of the West and the rails of the East, and that is pretty near the pith of this whole matter.

This lake and river are what have made the commerce of this city, not the railroads. These railroads were built because there was a canal and a river and a harbor here. And Chicago did not put in much capital in the railroads. If grain, coal, lumber and iron goes to South Chicago, Chicago will lose her hold on commerce and become a way station.

The next thing is that in carrying out the law regarding the Drainage Canal, we want the ship canal with it. We never could have got the law if we had not promised it to the people down the

Illinois river. Some other way might have been found to take care of the sewage besides taking it down to the Mississippi. We want a ship canal, and the general government is ready to build it, just as soon as these four interests (the city, the transportation companies, the Drainage Board and the U. S. government) are combined and have a united action, and that is what has been put before the Drainage Trustees today, in the form of suggestions, for their thought, and possibly their action.

I don't know that I could elaborate upon what to a business man looks to be so very important. I know that we cannot do it without the help of you gentlemen. You have the knowledge and you have the experience to take these questions and brain them into some action which will produce results. That is the reason that I have been in favor of immediate action. I don't think it is such a very great thing to ask the citizens of Chicago to stand $25,000,000 or $30,000,000 to make a great waterway through our river. I don't think the citizens of Chicago, when they thoroughly understand it, will hesitate one moment, and I believe if they ask the legislature to give us the right to an additional tax of an amount sufficient to carry this matter they will get it.

The Chairman—I assume, gentlemen, that no matter what you propose doing, there is a legal aspect to it, and we may attempt to do that upon which we will find a restraining hand, that of the law, is placed. Now, it would be wise to start out well advised on the law in the matter, therefore, I would call upon Judge Carter to speak upon this legal aspect.

ADDRESS BY JUDGE O. N. CARTER.

Mr. Chairman and Gentlemen of the Western Society of Engineers: I deem it a great compliment to be called here to talk to you for a few moments, especially as you have had the patience within the last few years to listen to my voice before. I suppose, gentlemen, you have learned the fact from your brother engineers, that we ofter repeat ourselves. Even my friend Cooley is guilty of that occasionally. I deem it a great compliment, but I come with diffidence, because I know the character of the men that I am talking to. The great works that have put our country to the forefront in commerce and in business, the ideas that have started these projects have come from men like yourselves. And when I look at the magnificent results attained by engineers, I never want to say that anything is impossible in this country.

I do not intend to dwell very long on this subject, in its legal aspect, to-night, because that part of the subject is always very dry. My judgment is, that most of the legal questions are, in a large measure, settled by the engineering questions. I found, when I was attorney for the Drainage Board, that the engineers had about as good an idea of what the law was upon a given subject connected with an engineering project as the lawyer, and usually much better than the ordinary lawyer, if the latter had not any experience with that class of work.

We have great problems here facing us with regard to the Chicago River, and some of them seem mountain high, possibly from the legal side of the question, because we have, with our business interests, in this hurried rush, in our desire to make money, in this great 19th century that has just passed—the most marvelous century in the history of the world, in the creation of material things —created, so Gladstone tells us, more than four times the material wealth than the 1,800 years previous had given to the world—I say, in our great hurry to make money here, we have lost sight of the marvelous future that was coming to our wonderful city. We saw this little river here, a mere mud creek, and yet it is what has made Chicago, as these men who have preceded me have said. Everyone has been anxious to use the river, and we have never thought to lay out its lines in such a manner as to be commensurate with the great needs of the future of Chicago. If we could have looked into the future 50 years ago, or even 25 years ago, and could have seen what Chicago was to be, the Chicago River today would not be what it is, because we would have protected the interests of all located there; we would have proper dock lines; we would have seen that the tunnels were not an obstruction to navigation; and we would have insisted on bridges being built in a different manner from what they have been built.

But, Mr. Chairman, the legal obstacles must, in a large measure, be overcome not by fighting these battles in court, but by getting these great interests, all the various interests, in harmony, all working together toward a common point, by getting all interests along the Chicago River—the railroads, the elevators, the business people, the owners of buildings, the city of Chicago, the Sanitary District, the State of Illinois, and the United States—by getting them all to agree on a common plan of action. The lawyer, in my judgment, who expects to settle these problems, all of them in court, will delay this work immeasurably. I have found, when I was attorney of the Drainage Board and in my experience on the bench, as well as in many other capacities, that when you had, seemingly, a collision of these large interests, that you could adjust them more satisfactorily and, in nine cases out of ten, much more cheaply, if you met as men ought to meet and tried to settle the matter without going into court. And if our friend, the Drainage Trustee—I see there is one of them here tonight—will permit me to say so, I think that is true as to the past history of the trustees. Some of the greatest mistakes—I am not criticising them for it, because they are made in all great undertakings—but greater mistakes have been made by carrying these great problems into court than in any other way. I may be mistaken, but that is my judgment at the present time.

I read not long ago of a jury that was instructed by the court very voluminously and very clearly what they ought to do. They stayed out a long time and did not agree, and it turned out that only one of the men was disagreeing. The judge was very indignant, and did what we don't very often do in this country, or perhaps ought not to do under the law. He scolded this man very vigorously and intimated that he was not a man of good judgment or good sense. And the juror said to him, "Judge, I am the only man that is trying to carry out your ideas, all the other men are against you." [Laughter.]

That is the trouble in endeavoring to settle a great many of these legal questions. The lawyer who thinks all of them are going to be settled by a fight in court is going to make a great mistake. He will find himself the twelfth juror. I had some experience with some of these engineers and I always tried to get an agreement. I remember the race that Brother Reynolds and I had as to some of the Santa Fe interests, and we finally settled it out of court. A lawyer must be like Bret Harte's "Heathen Chinee," "childlike and bland," but so wise that he cannot be readily taken in.

In a large measure, the law upon these questions is simply common sense, nothing more and nothing less. And if you try to settle them only to serve the interests that you are trying to protect, and lose sight of all other interests, they are bound not to be settled right.

Now, Mr. Chairman, I have said about as much as I ought to say and not as clearly as I ought to say it. But this is a great central thought with me. I have been discussing these questions for several weeks with the committee. The most important thing, gentlemen, for the river improvement is harmony of action of all the interests involved not only the public agencies, but the private interests as well. One great difficulty that we have with all of these public improvements is to get the people that have to bear some of the burden of taxation to look far enough into the future to see what the public needs are. I suppose I would be just the same as they are if I was similarly situated. They charge Brother Weare and Captain Keith with looking only after their selfish interests. Many of the critics are the ones that have the mote in their own eyes, failing to see where they are blocking the progress of the future in this great work. They told us a few years ago, within the memory of us all, that it was impossible from an engineering and a financial standpoint to build the Drainage Canal; they told us—business men and engineers—that when we did it would be an utter failure. And yet in one night, while we slept, the blue waters of Lake Michigan were turned south and were running once again over their ancient bed, and that which seemed a dream became an accomplished fact.

The same thing can be done with the improvement of the Chicago River. I have heard from my friend Captain Keith—we have been fighting, shoulder to shoulder, in this matter—and from some of the other commercial and vessel men, that if we don't do this work in the next two or three years that it means the death knell for the Chicago River commerce. I don't agree with them. I think they are short-sighted in that. I realize what we are losing. I have heard the facts tonight that convince me that it is true, and I have heard it before, but the Chicago River is not going to die yet; the logic of the situation will explain itself.

The people, when they realize the importance of these questions, will settle them right. You know, a few years ago it was reported in this country that Mark Twain was dead. He was in Europe at the time, and you will recall the dispatch that he sent: "Reports of my death greatly exaggerated." [Laughter.]

That is the way I feel, gentlemen, about the Chicago River, when I hear it charged that it is dead. When we see what great things the Chicago River—this little insignificant stream—has done for Chicago, and what it will necessarily mean for Chicago if the great commerce of Chicago is shut out of this river, we will not give up. That is what I feel like saying to these people who are pessimistic. I sympathize with them, and I agree with them, and work with them, but I say that they are pessimistic. I won't give up yet. Right here at this opening between the greatest inland waterways of the world, the great lakes on the one hand and the Mississippi River with its tributaries on the other, when we have just built the greatest connecting link between these two waterways, I am not one of those who will say that we are going to close the Chicago River. Never. The prospects for widening and improving and making the Chicago River equal in every way to what it should be were never brighter than they are tonight. And I want to see this Western Society of Engineers at the forefront in crystalizing and making public sentiment so as to carry forward this magnificent improvement to its ultimate successful result.

The Chairman—Gentlemen, I think it will be safe to assure the judge that we don't care four cents for the other eleven jurors. We had in the past an argument advanced very strongly and with great force in favor of this Drainage Canal, and it had nothing to do with commerce, but did have a great deal to do with our happiness, for we cannot have happiness without health. Therefore, I would call upon Dr. Reynolds, of the Board of Health, to give us his view of the Chicago River.

ADDRESS OF DR. A. R. REYNOLDS.

Mr. Chairman, and Gentlemen of the Society: I have not with me any figures, and in dealing with this subject we deal with statistics largely. I was just thinking that all this talk about death and murder of commerce and that sort of thing was comparatively new to me. I knew that there was such a thing as commerce and I had heard that it was going to be destroyed, but I knew that the lives of the people were in greater danger.

I know that if the death rate from impure water diseases that occurred in 1891 had continued until the present time there would be 50,000 fewer people in Chicago than there is today—and they would have died by these water borne diseases. That has always seemed to me to be the chief reason for the improvement of the Chicago River.

I have realized within the last two or three weeks that there were other interests, and many interests. The engineering interest that has built these great tunnels under the lake to the purer waters has been one of the agencies that saved the lives of the people I have referred to, and another reason is the educational influence of the daily press, who have repeated again and again the necessity of boiling the water before it was used.

I sincerely trust that the spirit of the law and the letter of the law will be carried out in this great work, as to the dilution. There has been some little talk lately that we were going backward, that we were going to violate the law in some way. But the result of the citizens' meeting today seems to indicate that there is to be no backward step, and I congratulate the people of Chicago on that fact.

The Chairman—Gentlemen, I suppose we can pass resolutions and do a great many things, but at last we have to go back to and fall back upon the governing powers, and without the co-operation of our Drainage Board I am afraid we can accomplish very little. But we have every reason, from what we have heard tonight, to say nothing of our knowledge of the personnel of that Board, to know that their hearts and their souls and their purpose is to serve the greatest good of those whom they represent, and hence the greatest number. Therefore, I would call upon Commissioner

Braden to present the question from the point of view of the Drainage Board.

ADDRESS OF MR. J. C. BRADEN.

Mr. Chairman and Gentlemen: The Drainage Board has endeavored to do just what the worthy chairman has said—to do the greatest good that we could in the past few years.

I recognized, as a trustee four years ago, that we had not money enough to complete the canal. We went to the legislature then, and some of the citizens here and some of the engineers at that time thought we could get along without as much money as we asked for and obtained. Some people will say: Why is the Chicago River in the condition it is today? Why should not the Drainage Board have seen the needs of the Chicago River, and made provisions for its needs? I want to say, as one of the trustees, that I saw fully the needs of the Chicago River, but I could also see that there was no chance at that time of procuring any further money for the drainage project until we could show the people some result. The Drainage Board worked with that idea. We often in our meetings said: "Well, once we can show the people the water running through the Chicago River, they will give us the necessary funds to take care of the river," and I think there is hardly any man who understands the question tonight but that will agree that it is necessary to spend money on the Chicago River to make it carry the 300,000 cubic feet of water per minute necessary, as provided by law, to be sent down the valley and to take care of the commerce of Chicago.

I want to say that it has always been the aim of the Drainage Board to take care of the commerce of the Chicago River as well as they can, in addition to its duties as a sanitary board. Our worthy Judge Carter here stated it right—the less the Drainage Board has to do with the law the better they are off and the faster progress can be made on the canal. I don't think we win many fights in court. Fighting costs a great deal of money and delays result in a great loss of time, and you never arrive at the result anticipated when bringing a lawsuit. For the needs of the river today, probably $11,000,000 would be required to place the channel in condition so as to take care of the commerce and so as to have a current in the river that will not interfere with boats going up and down the river. It will require the removing of the tunnels, the building of bascule bridges, and the widening of the river. I believe that when the tunnels are removed from the Chicago River that it will be done by the Sanitary Trustees. I believe that if the Secretary of War gave us a permit and we had the funds we could do it. But we have not had the funds, and today we haven't any chance of doing more than the building of one bridge on the Chicago River with the funds we have now in our possession or can anticipate for the next two years. We are in a position where our apparent income for the next year is $1,100,000, and our bonded indebtedness to be paid and the interest thereon amounts to over $1,500,000, a deficit of over $400,000. We have been able to sell some bonds, and have some money ahead, but we won't be long using that up on present contracts and immediate uses.

There are many questions before the Sanitary Board besides the building of bridges. Some of the real estate men seem to think that the only question is to pull out the old bridges and build new ones. We have made an arrangement with the city about the pumps for the tunnel at 39th street. That will relieve the present current in the Chicago River by forcing 120,000 cubic feet through the 39th street sewer, and the cost will be about $250,000. I have always believed that one of the pressing needs of the Chicago River was a controlling works somewhere in the neighborhood of Kedzie avenue, beyond the intake of the west fork of the South Branch. Then we would have full control of the water in the Chicago River. For instance, if the lake should rise or lower, they could telephone to the works from the mouth of the river and it could be taken care of readily. There would be no reason for the change in the current of the Chicago River if there was a controlling works at that point. You could have your current fixed at a mile and a quarter an hour—always the same, not fluctuating as it is now, and sometimes doubling in a few hours.

The rise or fall of this lake is bound to change that current very materially, no matter what you do with the Chicago River, unless such a work is built; even though you widen it to 250 or 300 feet, you will still have a fluctuating current in this river that boatmen cannot learn to navigate, on account of its being different from what it was when they last passed any given point.

I have been around the Lakes and there are a number of canals drawing water out of the lakes, but there is none of them that has not a guard lock or controlling works. This lake fluctuates in its level, sometimes in a few hours as much as 18 inches or more. With that change between here and Lockport, and all at one end, it makes a big difference in the current in the Chicago River. A properly constructed controlling works is an absolute necessity, as it now takes about ten hours to gain control of the river, whereas if a controlling works was built about Kedzie avenue full control of the river could be had at all times, and a complete stoppage could be had in about thirty minutes, which would be very desirable in case of an accident. The expenditure of, perhaps, $500,000 would build such a controlling works.

I want to say that I believe the crying need of the city of Chicago today is to take care of the Chicago River. This question of stringing out the work for several years is something that is going to hurt commerce. Commerce once taken away from the city of Chicago can't be brought back. Judge Carter has stated that we have made a stride in helping Chicago commerce here by a probable opening through to the Mississippi River of a waterway. If that waterway were an established fact I would say yes. But if we go along for the next three, five or seven years and allow this grain to go to the north of of us or to the south of us, or even after we have got the commerce established between here and St. Louis, it will be nothing like it would have been if we had kept all of our own commerce and added that to it. It means the building up of other cities at our expense. The man that pays taxes in the city of Chicago and fails to recognize that the improvement of its commerce makes his property worth more is blind. I am sorry that there are so many blind people in the city of Chicago. It is a bad thing to be blind, and blind people are a burden to the community.

We have had every question in this connection discussed for the last several weeks, and I hope that this afternoon we have arrived at a point where we can feel that we are making progress. The committee recommended this afternoon a committee of five, and with some other members to be added to it, making a committee of about a dozen. That committee is to examine into the needs of the Chicago River and the Drainage Board plans, and report back, and I understand that it was no reflection on the Drainage Trustees to allow them to usurp our places in that manner, for the simple reason that we want the public to understand that we are not deciding this, that we are simply presenting it to the people and letting them pass upon it as a jury. Now, when they report back it will be a hard matter to get legislation for $10,000,000 or $11,000,000, but that is what will have to be done. If we could go down to Springfield and get the half of 1 per cent, which would give us an income of probably $1,500,000 a year, we could continue the work, but that will not do the required work in the Chicago River that you people are expecting to see in the near future. The Sanitary District will have to have a bond to cover a part of this expense. And I believe that it is impossible for the taxpayers of the city or the Sanitary District to stand an expense of $11,000,000 more money without a bonded indebtedness. I believe it will probably be in that neighborhood. But we will have to have a bond, and we will probably not be able to get a bond for several years. We need to have united action, to understand the situation, to be able to get any legislation. I wanted to get legislation four years ago, and I found it a very hard matter to get it.

This committee has been given, by the motion this afternoon, until March 1st. I, myself, don't see any need for a committee any longer than two or three weeks, and I hope the committee will be able to act within the next three weeks and that we will be able to get a bill before the legislature by the first day of February. We have in our possession all the facts and figures necessary. I don't believe in any new schemes being put through; I believe in looking the situation over and seeing the needs, and working rapidly to the point. If this is done I hope to see legislation, with the idea that we are going to accomplish all the work within the next two years.

The Chairman—I think, gentlemen, that it will appeal to all of us that it is necessary to raise money for this purpose, and that it is perfectly right that the present generation should not be called on to pay all the costs of this great enterprise which will be of such great benefit for the many generations yet to come. It seems right to me that we should hear a little further from the commercial side of the question, and, therefore, it gives me great pleasure to call upon Mr. Chadwick to say something as to how the grain and commercial people of the city look upon this enterprise.

ADDRESS OF MR. WM. H. CHADWICK.

Mr. Chairman and Gentlemen: I am looking forward to something more than the subject of commercial needs alone, something more than the health of the citizens alone; I am looking forward to the day when we won't need all these bridges that are now being talked about; I am looking forward to the day when we will have the Lake Front Park beautifully decorated, when we will have a grand drive, starting from Park Row and going under the main stem of the Chicago River; I am looking for another big plan from this society—a subway from the West Side into the business district. I believe they are going to come. I believe the people of Chicago are waking up to the fact that we are a great city, and that the people who are here are not here simply for their health nor for pleasure, but that they might as well have health and pleasure now that they are here.

As to the question of raising money, money has always got to be raised from the same people. Real estate pays the greater part of the taxation—there is not much question about that. We have to show the owners of real estate and the people who pay taxes on real estate that their real estate is benefited in a greater ratio than their expenses. It is hardly just or fair to call upon the people, who have already borne a burden of about $35,000,000, to pay all the expenses of all these improvements that we now have in mind, immediately out of pocket. I asked a commercial man of this city, — a man who stands well in the community, a man who is accustomed to dealing in bonds and such securities (Mr. John Farson) — what he thought was the ideal bond, and he said: "You give us a 3 per cent bond, *free from tax*, and it will sell for over 100." Now, a bond free from tax, and issued under this municipality, partakes of the nature of a State bond, and there is nothing superior to it from such a State as the State of Illinois.

I do not see any reason, laying aside for a moment the constitutional limitation that is in some men's minds, why a bill cannot be drawn under which all the money can be had for the work to be done in the future. I do not believe it will be contested here that any money that is raised by a bill to be hereafter drawn, will look toward paying for anything except work that is to be done in the future. And then there is in the minds of the people always one thing threatening, and that is this old matter that this last Board has had confronting it, and which they have settled as far as they could, and that is the matter of claims. I believe there was somewhere in the neighborhood of three-quarters of a million of dollars in claims turned down, and that is in the way all the time.

Now, I believe it is just as well to look at the proposition as it is in the back end of a man's brains. They do not always speak out, but all the time there is lurking in the mind of the business man that some way or other money may be got, and some way or other money may be misapplied. I do not believe the people would favor, in any manner, the use of any money which hereafter may be had for the uses of the Sanitary District of Chicago should be otherwise applied than for the payment of work to be done hereafter.

I have always felt that when we came to the question of getting money, we would have to face that thing. I have always felt that that point would come up, and it would be mooted in the papers as heretofore. I am not criticising any individual member of the Board. I have great faith in this new Board, and I think they are going to do the right thing, and as soon as they can.

Speaking for the people I represent, I know how they feel, and I am anxious to see proper legislation had this winter at Springfield. Therefore, I hope that this conference of engineers, lawyers and men of other professions will come to a focus just as speedily as possible, consistent with the great scope of the work they have to cover.

The Chairman — Now, all this money that is going to be raised and spent in the future has to be done on the recommendation and practically under the individual direction of one head, and fortunately for our profession; that it will be honestly handled; that head must be an engineer, and I would call upon the chief engineer of the Drainage Board, who is one of our loved past presidents, to say something to us—Mr. Randolph.

ADDRESS OF MR. ISHAM RANDOLPH.

Mr. Chairman and Gentlemen: Inasmuch as the commission is about to take charge of the future plans of the District, I think it would be improper for me to speak of the future. I can only speak of the past, and not indulge in prophecy.

You all know what has been accomplished in the years which have passed since the 3d of September, 1892. You know that the greatest artificial channel now existing in the world has been created. You know that that channel is spanned by bridges of the most modern construction, and you know that everything which this district has been able to do to save the navigation has been done in the construction of the channel.

In carrying out these plans we have expended for this work, for right of way, construction, administration and interest account, something over $34,000,000. Under the terms of all contracts, no bills for construction can be paid which are not approved by the chief engineer. I have adjudicated extra claims amounting to $713,000. I have recognized the justice of $126,000 of that amount. There are now pending, or threatened in the courts, claims amounting to about $1,900,000. Of course, these are inflated claims. The contractors who bring these suits don't expect to get judgment for anything like that amount—for anything like the amounts which they sue for. And I am very confident that we can sustain the justice of our cause in refusing to pay any of these claims which have been pressed against us.

This much for the past. What have we accomplished in the way of giving Chicago health? No man can cross the Chicago River today without a feeling of delight when he sees the flow that goes by, as compared to the water in the river in the years that are past. As I have said, I will not touch upon the future, because that is in the hands of the commission. And the story of the past is told in very brief language.

Mr. Chairman—Gentlemen, we can't let the past be forgotten. A great work has been accomplished up to the present time, and that which has been done makes possible that which must be done and which will be done in the future, and I think it is quite right that we should pay our respects to, and hear from, a former member of the Drainage Board, and who happens also to be a past president of that board. Now, when I call upon this gentleman to speak to you and refer to the past, some of us here and some of his friends who love him hope it may be in his hands to do something in the future in bringing together those great interests — State, National and City governments. Gentlemen, I call upon Mr. Boldenweck.

ADDRESS OF MR. WM. BOLDENWECK.

Mr. Chairman and Members of the Western Society of Engineers : I did not really expect to be called upon this evening to say anything upon this subject. I came here to listen and to get information, but as long as I have been called upon, I suppose it is no more than right to say a few words.

In the first place, I would say if the Sanitary Trustees had started out to improve the Chicago River and to look out for navigation, there is one thing certain, and that is, that we would have no Drainage Canal today. The first thing that the trustees started out to do when they took this matter in hand was to complete the channel, so as to give an outflow for the lake waters through the Chicago River. If we had started in on the Chicago end to do this work, I am sure the people never would have given the money to complete the work. As you know, they occupied something like two years without starting this great work. It is like every other great work, the beginning is hard, and it takes some time before the different minds that are at work can concentrate upon a certain idea. I remember distinctly, on being elected as one of the members of the board, having a consultation with one of the old trustees, and he asked me what was my policy in regard to the construction of this canal. I asked him what he meant by that. "Well," he said, "do you intend to carry out this law ?" I said : "I most assuredly do, or I should never have sought this place. There is nothing for the trustees to do but carry out the law strictly according to the letter. And that means, that we shall dig the canal to carry a minimum flow of 300,000 cubic feet of water through the clay sections and to carry 600,000 cubic feet of water through the rock sections." He said : "You will be one of the most condemned men in the city of Chicago if you ever try to do it, and you will never complete it, because you can't raise the money to do it." I said : "Then there is only one way to do the work, and that is, to start and begin it. If we follow the same policy that you gentlemen have followed for the past two years, we will never complete the canal." That was what we had to do ; we had to make a beginning, and the beginning was made.

As regards the Chicago River, there is no question in the mind of any man who has watched the commerce of the Chicago River, but knows that something must be done. We can't deny that the current that is going through the Chicago River today is interfering with navigation. And, as regards what some of our valuable citizens have said, the right thing to do would be to go before the Legislature and have the law amended so that it will not have to carry 300,000 cubic feet per minute for the purpose of dilution. I know to my own satisfaction that that law as to the flow of water through the Chicago River will never be amended. I believe Mr. Cooley remembers that the old Board went down to the legislature and tried to have the law amended so as to get a less flow through the river, and they came back and had to proceed according to law and do their work over again. The legislators told them, "That is the law, and you have got to carry it out." And I do not believe it is too much for the dilution of the sewage in the Chicago River. There is no question that the city of Chicago creates more sewage than any other city, according to its size. And there is no question in my mind that the people of the valley will never permit a less flow than 300,000 cubic feet per minute.

Now, as regards the obstructions to navigation, the most serious obstruction is the Washington street tunnel, and I claim that, if the proper course had been pursued, that that obstruction would have been removed by this time. I don't agree with his honor, the mayor, that the Washington street tunnel should be removed by the railway companies and the railway franchises considered afterward. I say that the Washington street tunnel and the railroad franchises should be considered together; it is one and the same. It is the same thing as if a man goes out and wants to rent a building, and the owner says, "You fix up the building, and I will talk about the lease afterward." The railroad companies are not going to work and spend millions of dollars in lowering the tunnels unless they know they are going to get franchises. And if the mayor could not settle that work at one and the same time, then let the city go to work and lower the tunnels and have the railroad companies reimburse it when they begin to talk franchises.

That is one of the greatest obstructions to navigation in the Chicago River, and it is not owing so much to depth as it is to width. I understand that a great many of the large vessels are able to cross the tunnel but they get stuck on the sides. Now, if the bridges were taken away and the center piers removed, so the boats could use the center, they would not have that trouble and they could carry more freight.

I don't know as I have any more to say on this matter. The subject has been pretty thoroughly discussed this afternoon. I am one of those who believe in the Chicago River, and I believe that anything that can be done by the citizens to retain our commerce should be done.

The Chairman—Gentlemen, I know that I voice the unanimous sentiment of the Western Society of Engineers in thanking our guests for accepting our hospitality tonight and for having so interestingly and instructively spoken to us. Now, in concluding the discussion, and before we say goodbye to each other and part for the night, we recall that it was the guns of our navy that settled our late war, and as our sailor man has said that he would wind up the discussion, I call upon Captain Keith to close it.

ADDRESS OF CAPTAIN J. G. KEITH.

Mr. Chairman and Gentlemen: What I have to say may be more expressive than eloquent. The proposition that we are confronted with today we knew nothing about twelve months ago. At that time it was an unknown quantity what damage or delays or obstruction the coming current would cause to navigation in the Chicago River. No one surmised that it was going to be nearly as great as it has proven to be. Therefore, we all hesitated about running away from here until we knew that we were hurt. That period has arrived. We are hurt. I will give you figures, I will give you facts, I will give you the whys and the wherefores and the causes.

Mr. Randolph here has treated me in a most considerate manner, and the trustees also. There would be times when a vessel was going up the river and we had to call upon them to shut the dam so that we could take a vessel out of the slip across the current that was striking her at right angles. At times there are not tugs enough to be had in Chicago to hold a vessel up with a current running against her, striking her broadsides.

I am now looking for freight for next year. Mr. Weare, I presume has got his elevators pretty well filled with grain. Mr. Weare, what are you going to do about it? You have got the stuff to go forward, I have the tools to move it with. Will I take your stuff as a matter of preference? No, sir; I can't do it. If I go to your elevators I am going to lose 7 to 8 per cent of my carrying capacity. That is, on large carriers. It does not affect the small carriers, but the large carriers can't come here at all. Now, I will say, unless I can come here and get freight equivalent to what I can get from South Chicago or Milwaukee or Manitowoc, I don't want to come to Chicago. Now, for fear that the current might create more difficulty than we anticipated last year, I took and chartered two of my vessels to Manitowoc and Ashtabula. I contracted for 100,000 tons of coal at ten cents below Chicago rates. I profited by the action. We carry grain from Manitowoc for ⅛ and sometimes as much as ¼c less than what we will carry Mr. Weare's grain for. We carry it from South Chicago for ⅛ and I believe as much as ⅜c less than from Chicago, last year.

Why is this? One reason is that we are short of cargo when we are here, and another is that the terminal charges are so high. Those same vessels that were trading to Manitowoc last year I contracted for their towing for $10.00 in and out of port. The docks were a short distance from the lake and the towing was not hazardous. At Manitowoc, they have gone in there for $10.00 and sometimes $5.00, and sometimes without the cost of a dollar. Those vessels came here two or three times, and in one instance they paid $140 for a towing bill, and in another instance, $107 for a towing bill, and going up the river toward this end of the canal, they grounded right in the middle of the river. After they had passed over the tunnel they grounded near Main street. The river was three feet lower than ordinary at that point. The Drainage Board had the river blocked for some cause or another for about seven days. In order to cleanse the river they let the current go through rapidly. In that way we lost 24 hours on the bottom of the river. That same vessel, in going through the draw at 16th street, as soon as the current struck her she stuck in the draw and broke her rudder. It cost nearly $1,200 to repair it. These are all instances that militate against the Chicago River. Of the boats we have had trading in the Chicago River, one of their tow bills was $259; another, of the same size, was $450; and the damages were $450, and $850, and $860, in the Chicago River, where, if they were going to other lake ports they would escape all this.

These are some of the facts that are not speculative; they are not theoretical; they are actual facts, and the money paid for our experience. Another fact I would mention, it will take very often a half day to go to the dock and another half day to come down. In the night we cannot risk moving against the strong current; we will lay over to take it in daylight. There is the night lost. Ships run at night as well as in the day time, when they have the room.

And, furthermore, there is another feature that few take into consideration, and that is that the steel boats displace the wooden boats. A steel ship is a more profitable carrier than a wooden ship; they will carry in the neighborhood of 20 to 25 per cent more cargo than a wooden ship of the same dimensions, but a wooden ship will stand more battering than a steel ship. A metal ship was never built to strike anything but water. She is not built to strike the obstructions in the Chicago River. I thought we could navigate the Chicago River with a cargo greater than experience has taught us we can do. Take these steel ships moving up and down the river, when they strike one of these obstructions it leaves a dent in her bow that is an eyesore and costs a great deal of money to repair.

With the current there is in the Detroit River or in the New York harbor (and other harbors) I had supposed we could manage a less current in the Chicago River, but in both of these places and in nearly all the other places where they have a current they have a great deal more room than we have. When we come to move a vessel in a place one, two or three feet wider than the boat, and dragging on the bottom she does not answer her rudder. Ship owners at Buffalo, Cleveland and Detroit don't propose to send their property to Chicago to come in contact with that. They are not trying to take care of Chicago interests. It is their own interests first. I have letters from people owning ships in other ports, saying: "Load our vessels at South Chicago or in the North Branch, but on no condition go into the South Branch." They are right.

Now, the question arises, who has the greatest benefit from these vessels coming to Chicago. Is it the carrier, or is it the country? I hold that the country, back in the interior States, has by far the greater interests. Competition in tonnage has made it so close that we can scarcely exist on the ordinary rates we have received. It is not a matter of choice, but a matter of compulsion. We have too many ships. And there is where it is asked if your Drainage Board will continue the canal to the Mississippi. Gentlemen, in my opinion, it will be done within the next decade. We want it; we must have it. There are millions of dollars in the lakes. Let us get it out. We are carrying 9 per cent of our foreign trade, we are carrying 2½ per cent of the European trade. If our steamers could get at it they could carry a good part of it. If we can't get 14 feet of water, give us 12; if you can't do that, give us 10, and I think that 10 feet of water would take the largest boats on the lake out to sea. There is always one time in the year when you can get a vessel up and down the Mississippi; that gives a chance to go and come.

Gentlemen, it becomes us to look to the Chicago harbor, to open it up, to make it as accessible as other harbors are, to invite foreign commerce to come here. There is no reason why it should not be a port of entry as well as some of our seaport towns, and it will be, provided we do our part. No sane man would undertake to move a vessel with the current that we have running in the Chicago River today. It means destruction. I would not think of it for a moment. You can't do it profitably. If that current is continued during the summer you may just as well build a stone dam across the Chicago River as to let it be as it is at the present time. And, commercially speaking, if you have ⅛ to ¼ of a cent against the port of Chicago in favor of another port, there is a dam 100 feet feet high across the Chicago River.

Mr. Braden has stated about the claims that have been raised—and probably quashed—of contractors and others. I will state to the gentleman, who is a member of the Board of Trustees now, that there have been quietly working, claims that he little knows about, and the claimants will follow them and follow them strong when the time comes. I, as the Chicago representative of the Lake Carriers' Association, an association with probably $150,000,000 back of us, can say that we have the Senators and Representatives of eight or nine States working in the interest of these claims. These claims have been properly reported to the president of our committee, and the matter will go before the Secretary of War. There will be thousands and thousands of dollars that will have to be paid. I think that we have reasonable expectations to have it so. The Secretary of War says that there shall not be a current greater than 1¼ miles an hour, although our United States engineer has stated that at places in the river it is as high as two miles an hour, and recommends that it be left in the hands of the Trustees and regulated as they see fit. I don't know where he gets his authority. If it was two miles it would not be so bad, but I am convinced that there are three miles running today. What can we do with that?

Our commerce will have passed away before you can lower the tunnels and get the bridges out. You can't do it in four years, and if our embarrassment keeps up for four years, as it was last year, the commerce left will not be worth saving. I don't care what you do, it is not in your power to save it.

At the meeting which we attended this afternoon, by what was known as the majority report it was decided that the proper way to do it was to continue as we are doing and build the bridges as natural taxation would warrant, and that the best that could be done was about four bridges a year. There are 28 bridges in the river to be replaced with bascule bridges. So that will take seven or eight years to do the work. Gentlemen, you will not have any commerce worth speaking about by that time.

CIX.

TUNNEL AND CRIB CONSTRUCTION IN CHICAGO.

Paul G. Brown, M. W. S. E.

Read Dec. 9, 1900.

If an engineer who, in 1861, when the first lake tunnel was planned for the city of Chicago with her 120,000 inhabitants, should have predicted that the year 1900 would see situated in Lake Michigan five intake cribs and under the bed of the same waters twenty-two miles of tunnels, with a daily capacity of 615,000,000 gallons (and with 1,801 miles of pipe for distribution through the city) all to supply water for the residents of Chicago, he would have been styled a "dreamer." Yet, such is the situation today. The first tunnel to the two-mile crib was put into service in 1867, and from that time until 1895, additions have been tacked on to this tunnel system; piece by piece added to the pumping stations, and pipe after pipe added to the delivery, so that no system in the world could show such a low efficiency, or such radically absurd hydraulic conditions, nor so inadequately serve the purpose for which it was designed.

It remained for Samuel G. Artingstall, city engineer, in conjunction with John Ericson, his principal assistant, who was in charge of that branch of the bureau, to design and have adopted by the city council, a plan of a system of tunnels, pumping stations and delivery lines, so that an abundant supply of pure water is furnished to the residents of Chicago. This plan has been carried forward by Lewis B. Jackson, city engineer, 1895–1897, and completed by Mr. John Ericson, city engineer, 1897–1900.

No reliable statistics are to be had, but the total cost of a pure water supply to the city of Chicago has been in the neighborhood of $65,000,000 and fifty human lives. If three-quarters of the sum were applied for labor, continuous employment for forty years would be furnished to 2,027 men.

The cost of the tunnels, cribs, pumping stations and delivery systems are in the neighborhood of $15,000,000. The first tunnel to the two-mile crib, 10,567 feet long, cost $457,845, or $43.30 per lineal foot of tunnel. The details of this tunnel construction are of interest, as up to the present time the system is practically the same, save that the tunnels being larger material could be handled cheaper. I quote from a recently published article:

"This tunnel was practically circular, but the height was made

5 feet 2 inches and the width 5 feet, the top and bottom being circular. This form of section was adopted in order to facilitate the striking or removal of the centering, and has been adopted in all the latter tunnels. The same allowance of 2 inches is made in all cases, regardless of the diameter of the tunnel."

Work was commenced at the shore shaft on March 17, 1864, by the sinking of the cast iron cylinders for the 9 foot shaft. The shaft below the cylinders was lined with 12 inches of brick and had a clear diameter of 8 feet. From the bottom of the shaft a drift was made 50 feet westward, with a chamber for mounting the transit to give the line of the tunnel. Work on the actual tunnel was commenced May 26, 1864. The tunnel entered the shore shaft by a bell mouth, increasing in diameter from the normal 5 feet to 6 feet at the shaft in a distance of 20 feet. This was lined with three rings of brick, but the tunnel proper was lined with two rings of 4 inch brickwork, and the cavities outside the shell were filled with solid masonry, as it was found impossible to tamp them properly with earth. The upper arch was built on a ribbed center of boiler iron, which diminished the clear space within the tunnel only 4½ inches, and thus allowed the cars to be run to the face of the excavation, which was usually 10 to 20 feet in advance of the masonry. The iron center was 30 inches long. About 24 inches of masonry was laid at a time, and, as a rule, it was found safe to strike the center within 15 minutes after the arch was keyed.

It was found that the masons could build the upper arch without making the excavation larger than the space required for the brickwork. This was done by driving the last four or five top courses of brick into well-tempered cement mortar first thrown into the cavity. The driving of the bricks effectually filled the spaces which could not have been reached by hand. The toothing of the masonry furnished a guide in driving the bricks. The lower arch was built to templates as in sewer work, and was kept about 6 feet in advance of the upper arch. The excavation was generally through stiff blue clay, which seldom required bracing if not left for more than 36 hours. Small pockets of sand and quicksand were met with, and occasionally boulders, but very little trouble resulted. A dangerous and unexpected difficulty was the presence of inflammable and explosive gas.

Work was prosecuted night and day by two sets of miners and one set of masons, working eight hour shifts for six days in the week. About 750 feet from the shaft, two temporary chambers were made, one on each side of the tunnel, with which they were connected by small, short openings, all supported by timbers and planks. A turntable was placed in the tunnel at the connection between the chambers, and this permitted cars to pass each other and enabled trains to be made up. The second set of chambers was made 1,000 feet further on, and others were made at intervals of 1,000 feet. The passages, however, were lined with brick carefully groined to the tunnel lining, so as to prevent the "creeping" of the clay to any opening left, which would cause the brickwork to crack. After the work had progressed 1,000 feet, mules were used instead of men to haul the cars. The ventilation was at first effected by a 6 inch tin pipe carried to the furnace of the hoisting engine above the shaft, but afterward 8 inch pipes were used and a ventilating fan and engine were installed.

A 4 inch Pike transit was used for the alignment of the tunnel, and was mounted on a tower 166 feet west of the shaft, and sometimes placed in the back drift or chamber of the tunnel. When the masonry had progressed some distance, a 6 inch tube was sunk from the ground to the tunnel, 280 feet east of the shaft, through which the line was plumbed. The "trimming" gang which worked before the masons, consisted of four miners and four men to wheel the cars to and from the nearest chamber. The foreman set lines and "patterns" for the masonry. This shift carried the excavation on five feet and trimmed it to the outside shape of the masonry. The masons' gang consisted of three masons, one mortar mixer and four or six helpers. They laid an average of 12 feet per day, for the whole work, and sometimes 15 feet per day. The main mining gang, which followed the masons, consisted of four miners and four pushers.

It was at first proposed to sink three intermediate mining shafts, but these were not built, work being prosecuted only from the shore shaft and intake shaft. The crib for the intake shaft was hexagonal, with 58 foot sides, and a height of 40 feet. The inner well was of similar shape, the walls of the crib being 25 feet apart, and the space between them being divided into seven compartments. Three of the sides had each an opening or inlet port 4 feet wide and 5 feet high. The crib was launched July 24, 1865, and towed to its position, where it was, after some difficulty, sunk by filling the compartments with loose rubble, and then trimming it by pumping in water. A storm disturbed the work, however, and shifted the crib slightly, necessitating a slight deviation in the line of the tunnel. The intake shaft is composed of 9 foot cylinders, with sliding gates. When the bottom was reached, a 50 foot drift was driven eastward for the alignment of the work, and for handling the cars at the foot of the shaft. Tunneling progressed at about 9⅓ feet per day, but when the tunnel had reached 2,290 feet from the intake shaft it was decided to run a timbered drift to the east heading, to be certain how the lines were going to meet. The two headings met Nov. 30, 1866, and it was found that the masonry at the east face was only 7½ inches out of line with that of the west face. The masonry lining met on Dec. 6.

Between the shore shaft and the pump wells was a gate chamber 16 feet inside diameter, divided into five compartments by walls having at the bottom rectangular gate openings 3 x 5 feet, 23½ feet below lake level. The tunnels to the pump wells were 4½ feet diameter. The tunnel between the shore shaft and the gate chamber was of the same size and form as the main tunnel. As the tunnel was finished before the gate chamber, a temporary connection between the shore shaft and the mouth of the old inlet was made by a timbered drift, 4 x 4 feet, driven from the shore shaft to a 4 foot brick well, 30 feet deep, sunk in the water, the well having two wooden gates just below the surface. When the lake tunnel was completed, the working chambers were filled up and the tunnel was filled with water on March 8, 1867.

The second tunnel to the two-mile crib was from Ashland and Blue Island avenues, and was 7 feet inside diameter and 31,490 feet long, costing $30.43 per linear foot. On the basis of a 5 foot tunnel, this cost would have been $18.41 per linear foot, as against a cost of $43.30 for the first tunnel, showing a gain of $24.89 in the cost to the city, of tunnel construction.

This tunnel was parallel to the first and near the same, no difficulty being experienced except in the sinking of the lake shaft, concerning which I quote the *Engineering News:*

"The intake shaft was sunk in the lake, near the existing crib, and a cross tunnel was driven from this shaft to the line of the new tunnel. In sinking this shaft great difficulty was experienced, in consequence of water passing from the old tunnel to the new work, and it was found necessary to introduce the pneumatic system. This, however, created a new difficulty, the air escaping up along the outside of the cylinder to the lake. The cylinder was sunk to full depth, however, and the shaft was completed, but when tunneling was commenced the water and earth came in so rapidly from above, through the opening made by the escaping air, the work had to be temporarily suspended. By means of a diver, the opening was sealed, but then water was found to be coming from the old tunnel, and the diver was unable to stop this leakage from the inside of the latter. It was then decided to pump out the old tunnel, when the leakage was traced to an original defect around the bulkhead placed in the short drift eastward of the shaft. This was easily remedied by closing the drift with solid masonry. The water was turned in again after 17 days, during which time the city supply had been taken from the old inlet basin.

After waiting for the filling on the outside of the new cylinder to become compact, which was aided by draining the water from it through small holes bored in the sides of the cylinder, it was considered to be still too dangerous to attempt to prosecute the work in the ordinary way. The method for overcoming this difficulty was described, as follows, by Mr. Chesbrough, in his report for 1874:

> After careful soundings through the small holes bored in the sides of the cylinder, the clay which was known to be very firm originally all round, was found to be very soft for about 3 feet out on the southeast side, from the bottom of the cylinder to the bottom of the lake, the effect, no doubt, of the escape of compressed air on that side. It was determined at first to drive pieces of 2 inch bar iron above and around the sides of the drift, and then to close the joints between them by another layer of thinner wrought iron. It was afterward determined to put another floor of wrought iron a few feet above and in a horizontal position. This was composed first of fan-shaped pieces of 2 inch bars with close joints, which were covered above with a layer of ¾ inch bars. After this was done, it was found that the influx of soft mud below the floors had been completely checked.

The third tunnel to the two-mile crib (forty feet below the bed of the lake) was begun in 1886 and 1887, and extended to the two-mile crib in 1895 and 1896. The last 6,000 feet of this tunnel cost $16.00 per linear foot, or on a 5 foot basis would have cost $9.69; considering materials at the same price would show a gain of $33.61 per foot from the first tunnel built.

The average progress on this work was 24 feet 6 inches for every working day, and is probably the greatest on record, for any tunnel of equal length and size. The conditions were excellent for tunnel driving; the ground hard and firmly compacted, so as to stand without any timber, and yielding readily to charges of dynamite without breaking the ground forward of the excavations.

A driving shift excavated the upper section of the tunnel and was followed by a trimming shift that mucked out the bottom and trimmed the sides to the neat sections of the brickwork, nine feet in external diameter. This shift was followed by the bricklayers.

The writer has often been in this tunnel when a section thirty feet long, and on two occasions thirty-three feet long by nine feet in diameter, was excavated and standing without a single timber or support of any kind. This excavation was made by two shifts of miners, nine men in each shift, and 40.72 yards of material was excavated and hauled 4,000 feet to the shaft and dumped into the lake in sixteen hours, at a cost to the contractor of $1.04 per yard, or $2.46 per linear foot of advance.

The brickwork in place costing $5.96 per linear foot of advance, would make a total cost of completed tunnel of $8.42 per linear foot; or a cost of $11.30 per linear foot of completed tunnel at the average progress of 24.6 feet per day.

The four-mile tunnel consisted of 9,139 feet of 8 foot tunnel and 25,200 feet of 6 foot. The Commissioner of Public Works in 1892 said in his annual report that the location of this tunnel was unfortunate, and so it was. Five years were required to complete the work. The original plan was for an eight foot tunnel. The location of the shaft on shore was changed, large quantities of quicksand being encountered. When a new shaft was finally sunk and the eye turned, no progress could be made, the material being swelling clay and quicksand. Air locks were installed and the pneumatic method tried, but with no better result. Then a hydraulic shield was installed, only to be abandoned. Two six foot tunnels were finally driven at a lower elevation, in the firm clay, under the pneumatic method. Later the two sections were united in one 8 foot tunnel, which was finished in 1892.

A tunnel was driven to connect this system with that from the two-mile crib at Desplaines and Harrison streets. A very interesting problem was now presented: How was the connection with the old tunnel system to be made, without shutting down the station and pumping out the tunnel? The problem was solved by Mr. Wm. Innes, then foreman of the city work.

By the aid of a diver there was hung in the shaft, at an elevation just below that of the proposed connection, a cast iron ring slightly smaller in diameter than the shaft, and the joint between the ring and the shaft wall well caulked. The diver then bolted 12 x 12 inch pine timbers to the cast iron ring and caulked the same with oakum. Pig iron was then placed on the platform thus formed, until sufficient weight had been added to overcome the upward pressure due to the head of water. A pump was then placed in the shaft, the water removed and the connection satisfactorily made.

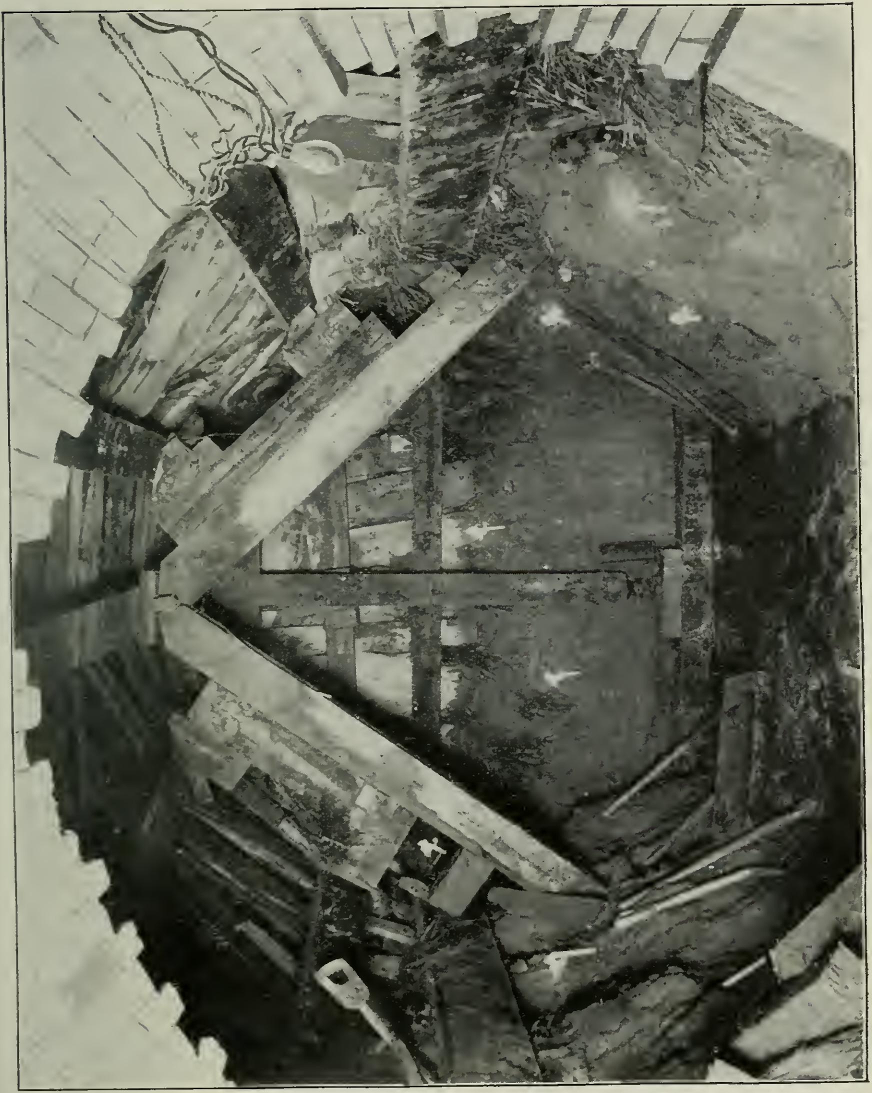
The Lake View tunnel, six feet in diameter and 10,000 feet long, was begun in 1889 and finished in 1895, at a cost to the city of about $700,000. This tunnel was in earth and "earth and rock," and was finally completed by lowering the grade until the entire section was in solid rock. This was done after a section 1,250 feet in length from the intake crib had been abandoned. Tunneling had progressed satisfactorily until that station was reached, when the water began to flow into the section through the sand and loam in the face of the drift. The same continued until the drift was filled, the water rising in the shaft to lake level. An air plant was installed and clay dumped over the hole which had been located in the bed of the lake; the water was then forced out by air pressure, but soon again filled the drift. A bulkhead was built in the tunnel by a diver, and the shaft reclaimed for the continuation of the work at a lower level.

The 68th street tunnels are 25,511 feet in length and cost $741,371. The construction of this tunnel system was a most difficult undertaking. The rock elevation leaving only 25 to 30 feet of softer material—clay, sand and loam between the rock and earth. No less than eight abandoned drifts lie under the bed of Lake Michigan off 68th street. The only system of tunneling followed was that of underpinning. If the material would not stand long enough to be timbered, compressed air was applied and the underpinning process again followed. The result was that between the air blowing out and the water coming in, the bed of the lake was in many cases punctured, the drift filled with water, and many feet of tunnel lost.

I do not think there was a single case where diversion was necessary or a loss of any tunnel would have followed, had the underpinning system (to which Chicago contractors and miners seem to be securely bound) been abandoned. Caps and batter posts could have been placed, over which laggen could have been driven, thus continually supporting the roof and not allowing any material beyond or above the tunnel section to be displaced or disarranged. The process would have been slow, but sure, and the hydraulic conditions of the finished sections would have been the best possible in a brick conduit; whereas at the present there are fourteen angles or curves between the crib and the wet wells at the station. This tunnel system should have been located 40 or 50 feet deeper and projected in the solid rock. It was deemed advisable, however, to rush the work in order to draw water from this tunnel for the World's Fair supply, but that immediate demand could have readily been taken from submerged pipes laid on the lake bed while the tunnel was being properly driven in the solid rock and, as a result, the city of Chicago would not have been heir to the most abortive tunnel system ever plotted on a map.

The Northeast lake tunnel was a remarkable example, both as to progress, workmanship and good management. The contractors took the work at a remarkably low figure, every one predicting that they would not complete their contract. They installed excellent plants, hauled their materials and spoil on cars with an electric motor—doing away with the large number of mules and drivers heretofore considered necessary—moved their brick, cement and sand in large crates by derricks and cars, so they were not once rehandled from the source of supply to the workmen at the face of the tunnel. Work progressed very satisfactorily until only a few hundred feet remained to complete the tunnel, when a strata of water-bearing sand and loam was encountered, making it necessary to install an air plant. A pressure of upwards of two atmospheres, I am informed, was carried in this drift, making rapid progress impossible.

Section No. 1 of land tunnel was satisfactorily completed by the same contractors. Section No. 2, extending in a southwesterly



Section 3 New Land Tunnel. Excavation and Timbering Through Bad Ground.

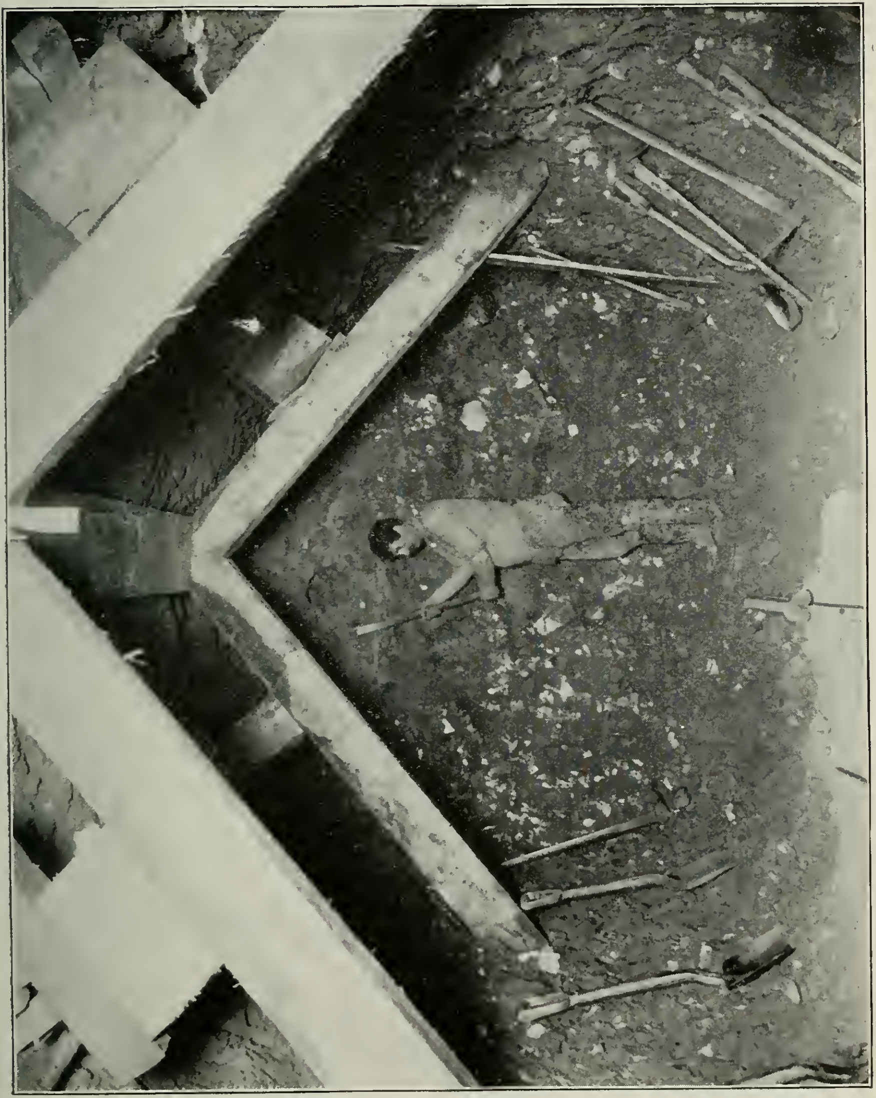
direction, being in rock and earth, was finished without encountering any difficulties.

The contract for section No. 3 of the land tunnel extending in a northwesterly direction, was let in 1895, the earth sections at $16.65 per linear foot, the rock sections at $15.90, with $2.00 per yard extra for rock excavations, $6.00 per yard for rock in earth and $6.00 per yard for masonry beyond the required three rings of brick. The tunnel is 8 feet 2 inches high and 8 feet wide inside, built with three rings of brick laid in cement mortar. The work was stopped by the contractors at various times while litigation was in progress, until November, 1898, when it was finally shut down, and the tunnel allowed to fill with water.

The contractors used the caps and batter post method of supporting excavations, using the caps and posts in a system of underpinning, the posts uniformly 8 feet long and the section excavated until the base of post could be placed on a level with the spring line of the tunnel, and the excavation made of such size that the timber set could be put in place, the excavation being from 100 to 200 per cent in excess of the normal section.

The section within and above the bents was first excavated and the timber placed, and after a progress of 40 to 60 feet the bottom was excavated and the bricklayers sent in to line the section. Often for a week or ten days, a section would stand thus timbered, sand, water and loam running through the timbering, the materials becoming continually softer on exposure to the air and often water. Upon the city engineer's protest against this dangerous and unsatisfactory method and his refusal to render extra estimates for rock in earth and masonry, the contractor shut down the work, and secured an injunction restraining the city from taking possession of the tunnel or the plants. This injunction was removed early in July, 1899, when the writer, on behalf of the city, took possession of the tunnel. There then remained, to complete the section, 1,500 feet of earth excavation, 400 feet of rock excavation, and 3,800 feet of rock excavation to be trimmed and lined with brick.

When the water was removed from the tunnel it was found that 66 feet excavated in one drift and 11 feet excavated in a second drift but not lined with brick, had caved in, the timber bents being broken, the entire normal section being one mass of earth, stone and broken timbers. Two houses over the end of the first-mentioned drift sunk several feet and were abandoned. This cave-in section was re-excavated, the roof being supported by jacks and uprights until a progress of 7 to 10 feet had been made, when longitudinal crown bars were set in place, the bottom removed, and the section lined with brick. The cost of the finished work in this re-excavated mass of timbers, plank, sandy loam, etc., was $45.00



Section 3 New Land Tunnel. Showing Method of Timbering.

per linear foot as against upward of $60.00 per linear foot paid to the contractor for the completed work when the excavation was through the virgin soil.

Work progressed in this heading continuously until January 9, 1900, when the excavation was complete, two mining shifts and one mason shift being employed each day. The first mining shift drove the heading above the floor line, 2 feet from the bottom of invert, and placed crutches and crown bars, slabs, etc., properly blocked and wedged into place. The second mining shift excavated the invert and trimmed the sides preparatory to lining with brick. When the ribs were set up for the brickwork in the arch, the crown bars were blocked from the ribs and the crutches removed.

A progress of 17 feet daily was made through boulder clay, under the same conditions as existed during the period just preceding the shut-down by contractor (see cut), at a cost of $21.25 per linear foot. Two-inch holes, 2 to 3 feet deep, were drilled in the face and the bottom with clay augers, and 1 to 1½ pounds of gelatine 60 per cent dynamite used to loosen material. By drilling shallow holes, and shooting several times, each shift produced much better results than by using larger quantities of dynamite and deeper holes, there being less disturbance in the virgin soil, and hence fewer caves as work progressed.

Later the conditions changed (see cut). A very hard clay, mixed with about an equal quantity of broken rock, was found in the bottom of the excavation and up to the spring line, and above that point soft loam and sand with running water, making a very small excavation necessary until the upper crown bar could be placed and supported by jacks. Blocking was placed in the sides of the excavation at about the elevation of the spring line and midway to the face, upon which were placed two 6 x 8 timbers, forming an inverted V, the apex supporting a longitudinal 6 x 8 timber. On the outside of these crutches were placed other 6 x 8 longitudinals, blocked and wedged from the crutches, which could be removed after the ribs were set up for the brickwork, the longitudinals being blocked from the ribs.

A bulkhead was placed at the face to make a firm bearing for the sill, which supported uprights properly wedged and blocked so as to carry a load upon longitudinals before mentioned. The bars at the sides and the crutches being placed, the voids were packed with slabs. Hay was used in liberal quantities to prevent the slipping of wet materials. These conditions continued to the completion of the work, reducing the average progress to a little less than 15 feet per day, and increasing the cost to $24.41 per linear foot, as against a cost to the city under the contract system of upward of $60.00.

Considerable improvement has been made in the construction of intake cribs since the old two-mile crib was placed, in the early sixties.

This crib is of wood, hexagonal in shape, filled with riprap and concrete; the superstructure being of granite, limestone and brick. The elevation of the top of the portholes through which the water passes from the lake to the well of crib is zero, city datum, or lake level at low water, so that the crib was constantly in danger, both from anchor ice and the large fields of drifting ice that invade these shores in the winter months, being a constant menace to the ports and also to the safety of the crib.

Later, a protection breakwater was placed around this crib, with an opening 40 feet wide, to admit tugs and for the water supply. This procedure, while affording protection to the crib from the fields of ice, only added to the danger of shutting off the water supply by the ice; the current being so great through this one opening that anchor drift and large fields of ice are drawn into the ports of the crib, making it necessary to employ thirty men and two tug boats during the winter period.

The crib could be maintained with four men had the ports been placed near the bed of the lake, or had ports been placed at a low level in the protection breakwater.

The actual maintenance charge for this crib is $16,000 annually, as against $4,000 for another crib, and the conditions are such that the only remedy lies in the extension of the tunnels and the removal of the crib, which should be done at an early date. The cost of the proposed extensions would not exceed $200,000, while the annual maintenance fee, capitalized at 3½ per cent, exceeds $450.000, showing a net gain to the city of $250,000 by the extension, and a greater gain in that better water would be supplied.

The Hyde Park crib is constructed on the same general lines as the two-mile, save that the ports in the protection breakwater are at a low level. The newer cribs are built with a timber bottom, on which are constructed the crib walls—two concentric rings of steel with radial bulkheads, which are filled with concrete to the level of the top of the water. The ports are at a low level, and but very little trouble is experienced, as a result of even a very severe winter.

Even with these improvements it was still necessary to keep a large force of men on the cribs, hoisting ice day and night from the wells. It was thought necessary to leave the well area entirely open. Ice would form, and the ice-laden water passing through would leave its deposit of slush, anchor and drift ice on the crib walls and around the gates of the intake shaft, necessitating the men working constantly night and day to clear the openings to the shaft. It seemed to me that were the well room enclosed and the temperature of the room kept a few degrees above the freezing point, this trouble could be avoided.

The experiment was tried at 68th street, and was so successful that four men only were required on the crib during the winter; whereas twelve had been employed the previous year. The fish screens were also allowed to remain over the intake even in the coldest weather.

The next year the four-mile crib was similarly equipped, with a result equally satisfactory.

The Carter H. Harrison crib (a plan and section of which are shown) represents the highest type of construction of an intake crib. Circular in form, the large fields of running ice are readily parted and continue on their journey without detriment to the crib or danger to the water supply; whereas a straight surface presenting a perpendicular line to the path of the field caused the ice to pile from the bottom of the lake to a height of 25 or 30 feet above the water, entirely shutting off the intake ports on that side.

The intake ports to the well room are at a low level, and that combined with the circular form of the exterior and a thoroughly modern heating plant in the well room, allows the crib to present such a defense that the most severe conditions will not be a menace to the water supply.

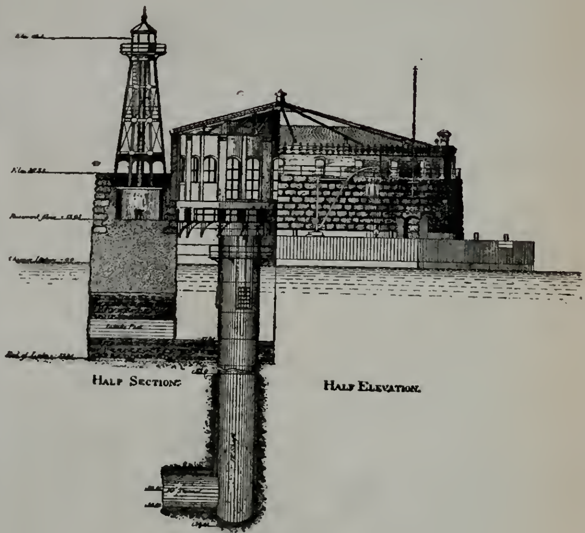
Light, comfortable quarters, bath rooms, with hot and cold water are provided, and good sanitary conditions prevail, so that few of us in our own homes have more physical comfort than the crib keeper.

The progress in crib construction has been very similar to that of the man-of-war. First, the light sailing frigate of wood with no defensive factors in her make-up, and by gradual development the armored battle-ship of to-day was the resultant. So it was with the intake crib; first, a wooden box floated into position and sunk by loading with stone, only to be battered to pieces by the storms, until now cribs of the Carter H. Harrison type, armored with steel, and presenting immense battlements of stone, are able to withstand any attack of nature.

DISCUSSION.

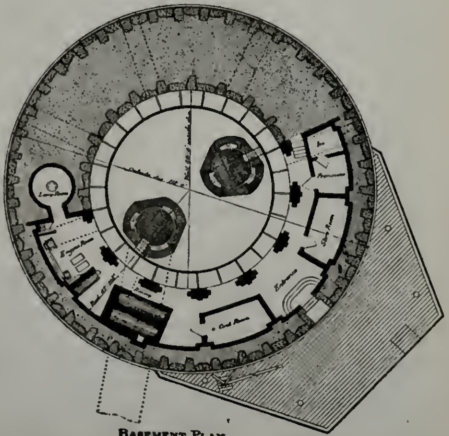
Mr. Wilson—I would like to inquire if he has any data as to the use of electric motors for handling the material as compared with mule haulage in other tunnels?

Mr. Brown—I don't know that any accurate data has been compiled, but it would be the cost of about two tons of coal every twenty-four hours, one engineer and one motorman, as against, if the tunnel were say 4,000 feet long, the cost of eight mules and eight mule drivers, to say nothing of the additional delay caused by

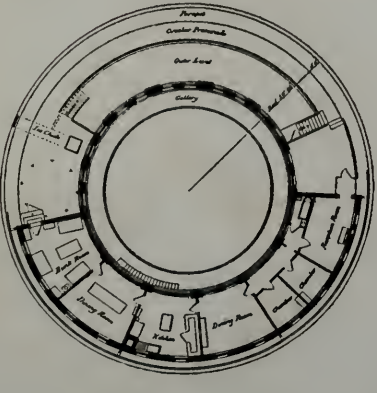


Carter H. Harrison Crib

Commenced July 1896. — Completed December 1899.
L. E. Mc Gann. Commissioner of Public Works.
John Ericson. City Engineer.
Scale.



Basement Plan.



Floor Plan.

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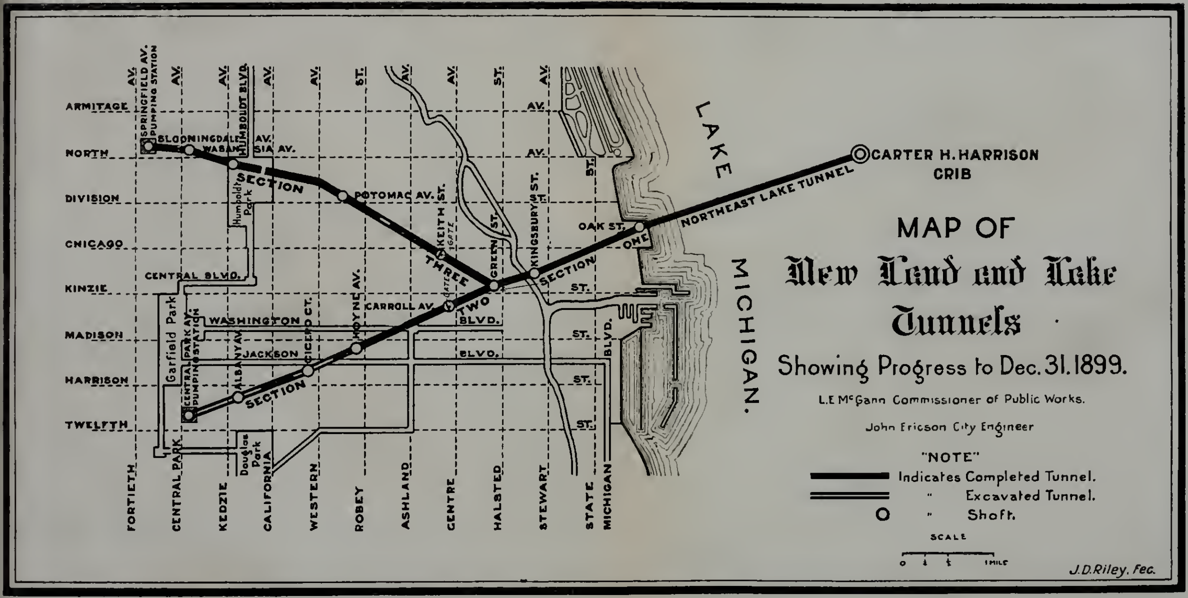
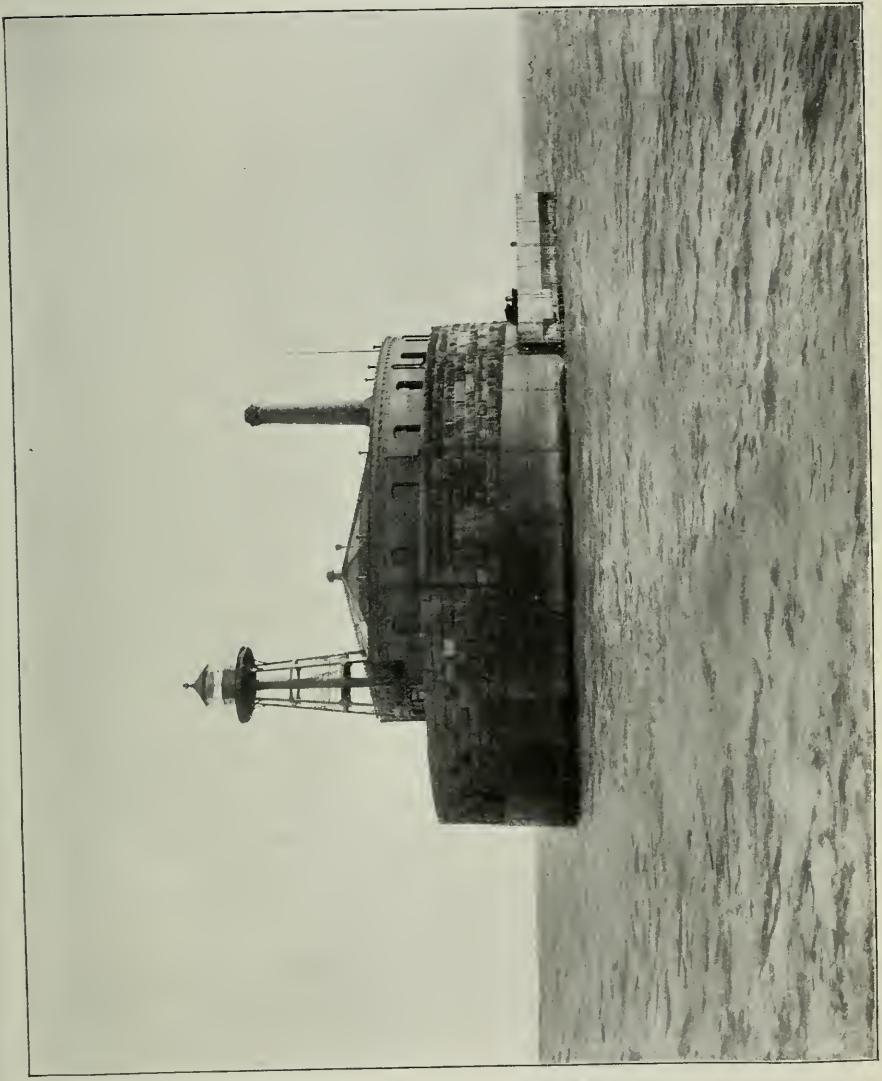
Brown—Tunnel and Crib Construction in Chicago.





The Carter H. Harrison Crib, supplying the New Land and Lake Tunnel.

the mules not being able to haul long trains of cars, that is, the material would have to wait—one mule train for another at a switch. In the first place the cost would be eight to ten times as great in the case of mule haulage as in the case of electricity, and a greater loss in moving the material. A motor car will haul from 8 to 10 cars, the tunnel being practically level.

Mr. Heidenreich I would like to ask Mr. Brown what wages were paid to the laborers and bricklayers?

Mr. Brown—The wages have varied from time to time. A few years ago bricklayers were paid $6.00 a day for a shift of eight hours. The foreman of the mining shift received $4.00 for the eight hours, and the five other men were paid $3.50 for the same time, and then there would be from 6 to 8 shovelers at $2.50, and common labor from $1.50 to $2.00 per day; there was no unskilled labor in the tunnel. But in recent years, owing to the labor organizations, the wages of bricklayers have been $1.00 an hour for all tunnel work, and the foreman received $1.00 extra; the miners received $3.50 to $4.00 a day. During the progress of some of the work here the miners have been paid $2.50. The section built by the Fitzsimmons & Connell Company was done with $2.50 labor, the ground being almost uniformly good. In the rock sections of Weir & McKechney's work, I don't know what they were paid, anywhere from $1.50 to $2.00 for miners, but the contractors, who have been the most successful, are those who have paid the highest wages. Recently I had occasion to hire some miners for work outside of Chicago, and I paid 50 cents an hour, and made money by doing so, because one man was able to do the work of two common laborers. The space in a tunnel is so limited that only a few men can work at the face, but the fixed charges go on just the same, so the man who can show the maximum result for his day's work is the cheapest for the contractor, if he is paid twice what another man could be hired for.

Mr. Reynolds—I would like to ask if the prices given on the tunnels includes the extras?

Mr. Brown—Those prices include everything any place I have quoted.

Mr. Reynolds—How about the McKechney contract?

Mr. Brown—It does not include the last $500,000, but that was a very recent decision—that is quite an important omission, however.

Mr. Artingstall—I will agree with Mr. Brown that the cheapest labor and the cheapest work done by the contractors is by paying a good price for their labor. They get competent men, and the cheapest work is done by the highest priced men. The last work I had we paid no less for good labor than $3.00 a day for the laborers in tunnel work, and as high for foremen as $4.00. And we paid for masons $8.00 a day for eight hours' work, but we got good faithful honest workmen, and it was done cheaper than by employing poorer men and paying them less.

Mr. Morehouse—I understood Mr. Brown to say that until Mr. Artingstall's system was adopted that the water system of Chicago was very defective, but I did not understand that he stated in what particulars it was bad and in what the improvements consisted.

Mr. Brown—I meant more especially the part of it referring to the tunnel system at the Chicago avenue pumping station. But it is just as it would be in any city where provision was first made for a very limited water supply, and then, as the needs were increased, the pipe system was added to, the original plant remaining about the same and the piping system being added little by little every year, without any regard for the size of the pipes.

Mr. Artingstall—Mr. Brown touched on one point which is of very great importance in this city, and I may say that most cities and towns, generally put their pumping stations near the source of supply and removed from the center of consumption. It may seem to be economy to do it, but it is not economy; it is trying to do as much as they can with the money they have to spend. The best way is the same as we are doing now—it is to put your pumping station near the center of consumption, and then from where your pumping station is, to radiate out in all directions. While it may be a good many miles from your source of supply station, there is the place for your pumping station, and let the water flow from the lake or river to those pumping stations, and not to put your pumping stations at the source of supply and then to pump your water by burning coal and all the expenses incident to it. If you start at the lake front you get but little pressure at the outskirts of the city, and you get a good many complaints for lack of water. If you carry water by tunnels to the pumps at the center of consumption you get more benefit than by spending a great deal of money for the expense of coal in trying to force water through the intricate lines of pipe.

I think that it is a very important point and well worth considering. We are getting to it now. It is not only in this city, but we know it in all other cities and towns. They should put the pumping station as near the center of consumption as they can get it.

Note.—This is clearly shown in the map of the new "land and lake tunnel," which shows the location of the new pumping stations at Springfield avenue and Bloomingdale road, and at Central Park avenue and Filmore street, some miles west of the lake shore, but nearer the center of consumption. The lake water—admitted to the tunnel at the "Carter H. Harrison" crib—flows by gravity to these pumping stations, and from there is distributed through the system of water mains to the great and growing population of the northwest and southwest portions of the city. The pressure of water in the mains will be greater and more satisfactory to the consumers than if the water should be pumped all the way from the lake shore.—Editor.

CX.

DESIGN FOR A CONTROLLING WORKS AT THE CHICAGO END OF THE DRAINAGE CANAL.

By Ossian Guthrie, M. W. S. E.

Read December 19, 1900.

This plan for controlling works for the drainage channel, to be located near the junction of the channel and river, has been designed by me for the purpose of maintaining a uniform current which the pilot may learn to navigate so as to avoid accidents to vessels, to afford immediate relief to vessels jammed across the river and held by the current, and to afford prompt aid to vessels stranded upon the tunnels. It is obvious that none of these desirable objects can be attained by any controlling works twenty-eight miles away. One set of controlling works, as the members of the Western Society are no doubt aware, is in existence at Lockport, at the end of the canal, thirty-four miles from the mouth of the Chicago River. It has been found however, that these works are so far away that in case of a vessel becoming jammed across the stream, as has happened several times during the season just closed, from six to eight hours are consumed in bringing the canal to a level so that the vessel may be released. Consequently, there has been a demand from the navigation interests concerned in the improvement of the river for a second set of works, to be located at this end, which will stop the current in much shorter time. Several members of the Board of Trustees of the Sanitary District have favored the construction of such works, and they were recommended by President Boldenweck in his retiring message, read December 5, of this year, in the following language:

> "On several occasions I have pointed out to the Board the need of a second set of controlling works, to be located at the Chicago end of the canal, at or near Kedzie avenue. With a proper construction of this sort, it would be possible to shut off the flow into the canal from both connections with the Chicago River, and thus give quicker relief to the vessels that occasionally become unmanageable in the current of the South Branch and jammed across the stream, through the carelessness of captains, or from other causes. At present it is necessary, in case of accident to a vessel, to close the Lockport works; but these are so far away that at least eight hours are consumed in stopping the flow. With such works at this end as I believe can be built at a moderate cost, and without preventing navigation between the canal and the river, it should not take more than from one to two hours to bring the river to a quiet level. Furthermore, in case of an accident to the Lockport controlling works, or of a serious break along the canal, a second set of works might save incalculable injury at Lockport and Joliet, while it would also be highly useful in case of repairs being needed at any point along the channel. Indeed, it seems to me that it should be a fixed principle in any construction where

human life and property are at stake to provide double safeguards. Should an emergency ever occur where the need of a second set of controlling works would be shown at disastrous cost, the Board of Trustees would never be forgiven by the public, and its members would never cease to reproach themselves for that lack of foresight."

An approximate calculation shows that with a suitable controlling works, such as is recommended by President Boldenweck, quick relief could be furnished with certainty to vessels caught by the current. At Main street, where one big boat was jammed across the stream, relief could be had in fifteen minutes; at the Fort Wayne Railroad bridge, where the Amazonas swung into an immovable position the day after the full current was first allowed through the canal, only about twenty minutes would be required; while at Washington street tunnel the effect of the closing of the controlling works would be felt within an hour. At this latter point, great relief would also be afforded to the vessels that frequently become stuck on the top of the tunnel, by the temporary rise of water due to the hydraulic ram effect of suddenly closing the works, the rise at this point being calculated to be about nine inches. At other points along the river it would also be very beneficial to have a temporary increase of a few inches.

For the purpose of stopping the flow of the Chicago River the controlling works proposed should be designed to withstand a head of sixteen feet. Under ordinary conditions this would be the utmost that could come against the gates, but if any extraordinary calamity should occur whereby the lower end of the canal should be opened beyond the control of the Lockport works it would be necessary to hold back the water of the canal east of the Chicago works against a dry channel below. This would be a head of twenty-five and a half feet with the lake at datum. By the plan proposed, this head could be divided between two sets of gates, each sustaining one half, so that the maximum that needs to be considered for each gate is the sixteen feet head.

The Sanitary District law prescribes that the canal after its opening must be a navigable waterway, which necessitates devising some means for passing the largest size vessels at all times through the controlling works. For this purpose the two sets of gates are arranged so as to form a lock, but the sides of the channel are left in their original condition instead of being walled with expensive masonry.

Essentially the device consists of using a number of balanced gates, each swinging on a vertical axis, at each end of the lock. The channel requirements are to allow a flow of 600,000 cubic feet a minute when the works are open, and to provide for a cross section 183.25 feet wide on the bottom, a depth of water of 24.5 feet with the lake at datum, and side slopes of two horizontal to one vertical. For the sake of reducing the velocity at this point the work has been planned to have a width of 200 feet between bulkheads.

It is highly desirable to have the controlling works so located as to shorten to a minimum the distance between the works and a vessel in trouble. To this end it might be desirable, and probably would be economical, to erect a cheaper and smaller set of gates for controlling the flow at Kedzie avenue, and another set for assisting vessels at Robey street or thereabouts. The structure for relieving navigation should be capable of being operated with the same facility that a bridge is opened or closed. It is also desirable that it should be so made as to provide a uniform flow through the river at all times, thus counteracting the effect of the varying head due to the fluctuations of the lake level. This fluctuation sometimes amounts to two or three feet in as many hours. A change of wind usually produces from a foot to a foot and a half in possibly an hour. Consequently there is a variable current in the river which it is hard for navigators to calculate in advance. During the past season the navigation men have made many complaints about the varying flow, and have ascribed it to the raising and lowering of the Lockport bear-trap dam; whereas it was probably due more to the change in the lake level than to any influence at the end of the canal.

By means of two automatic gauges, electrically connected with suitable operating machinery at the works, one being located at the mouth of the river and the other at the works, it would be possible to control the flow to any required speed of current. The regulator used on windmills throughout the country suggests the possibility of accomplishing this very desirable object.

Each set of gates is three in number, each gate being sixty-six and two-thirds feet wide. The central vertical post of each gate will consist of a hollow steel shaft, three feet in diameter, three to five inches thick and thirty-five feet long. The gates will also be made of steel, properly latticed and otherwise designed to meet the strains due to the pressure of the water. They may be either constructed in two parts and bolted together around the shaft after the latter is set in place, or they may be placed in position first and the shafts then stepped through them.

Each set of gates will rest on a pontoon that can be built anywhere and floated to the location. This pontoon should be 240 feet long, 18 feet wide and 8 feet deep, with bulkheads about 20 feet from each end and high enough to be level with the top of the channel banks when the pontoon is sunk to the level of the bed. The pontoon will be constructed of two members, each six feet wide and eight feet deep, placed six feet apart and decked across from out to out, with strong timbers bolted through from top to bottom. Through this deck, and extending nearly to the bottom, heavy steel sockets or wells will be inserted and firmly bolted to the structure with through bolts, so as to include the whole mass of concrete with which the entire pontoon will be filled.

To place the pontoons trenches will be dredged for each and carefully levelled. At the lower side of each trench a row of supporting piles will be driven to hold the pontoon in position before it is sunk. This row will also add to the resisting capacity of the structure against the head of water when the works are closed. After the pontoons are sunk the piles will be cut off level with the pontoon deck, or twenty-four and a half feet below datum. Through the center of each trench a row of Wakefield sheet piling will be driven to hardpan or bed-rock, from bank to bank. This sheet piling will be cut off uniformly about three feet below the channel bed, between the bulkheads, so as to leave a space of about two feet between the top of the piling and the deck of the pontoon. At the sides the top of the sheet piling will be level with the top of the channel banks.

The pontoons having been constructed, supposedly water-tight, they will be launched and floated to position against the supporting piles, when the flow of the canal will be stopped for a few hours and the pontoons sunk by placing in them sufficient concrete to nearly sink them, when the admission of water will be sufficient to cause them to go to the bottom of the trench. Then they are to be filled completely with concrete through openings left in the deck for the purpose, the whole work occupying only a few hours.

As soon as the pontoons are filled with concrete the current in the channel can be resumed, and the work of placing the gates begun. It ought to be possible to complete the whole structure within two or three months after the sinking of the pontoons.

It is obvious that there will be need of strongly supporting the tops of the gate shafts. This can be done by a strong strut extending up and down stream from the shaft, and abutting against a stone or concrete pier. The lower end of the shaft, being imbedded in the concrete-filled pontoon, will be firmly secured against moving.

To turn one of the gates it will be necessary only to open one of the smaller or wicket gates, with which each of its two equal leaves will be provided, when the inequality of pressure on the two sides will be sufficient to cause a rotary motion. In this way elaborate machinery can be entirely dispensed with for operating the works. Security from the freezing of water around the central shaft can be provided by making the sleeve at top and bottom about six inches larger than the diameter of the shaft for friction rollers and filling the entire sleeve from top to bottom with oil.

Though the gates will be balanced by equal pressure on each side of the central shafts when closed, they will be locked so as to prevent any possible motion. The flow of the water will probably be sufficient to open the gates and to close them after a slight starting power has been applied. For the starting power a small electric motor, taking its current from the nearest available source, can be used.

It is obvious that the number of gates can be varied so as to meet the best requirements of economy and efficiency. If three gates are used in each set, two will provide for the requirements of navigation and the third can be used to regulate the current. The clear opening available for vessels, by the three-gate plan, would be about sixty feet, or ten feet more than the width of the broadest vessels now afloat on the great lakes. The distance between the two sets of gates should be enough to allow clearance to the longest craft that may ever use the canal.

According to careful estimates that have been made by responsible contractors, the cost of such a controlling works as has been outlined should not be more than $200,000. On account of the simplicity of construction no heavy contingent expenses will be necessary in the construction; not a dollar will have to be spent for coffer-dam construction and maintenance or for pumping. The whole structure will be as little liable to injury or the necessity of repairs as the best constructed bridge, and built as described it should be as permanent as may be desired.

DISCUSSION.

Mr. Warder—As I understand it, we have one main passage for the handling of boats, and a secondary passage, where the flow of water is regulated?

Mr. Guthrie—No, both sides are alike. The other side may be used for the passage of boats, just as well.

Mr. Warder—You used the term by-pass?

Mr. Guthrie—It is not likely that more than one will be required.

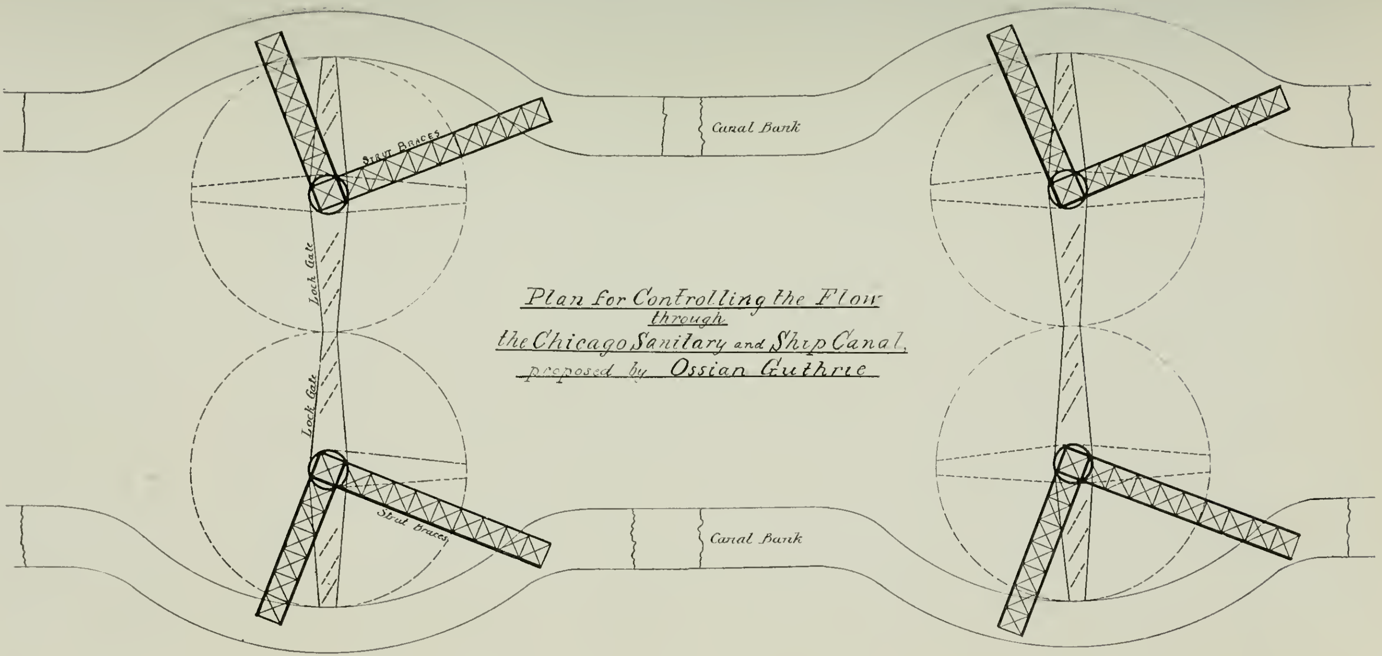
Mr. Warder—Use either side for the by-pass?

Mr. Guthrie—Use either side.

Mr. Seddon—Mr. Guthrie, I suppose this is to be closed when the conditions in the Chicago River are such that a boat has got into trouble?

Mr. Guthrie—Yes.

Mr. Seddon—That it will be located somewhere near Robey street and used to check the flow in the Chicago River and bring it up to the lake level?



Plan for Controlling the Flow
through
the Chicago Sanitary and Ship Canal.
proposed by Ossian Guthrie

Mr. Guthrie—That is the purpose of it.

Mr. Seddon—Now, I wish to ask, what do you think would be the condition in the river after that was done, after the Drainage Canal below this lock had drained down to the level of the crest of the dam at Lockport? Could you then open the lock, and if you did would you not have a worse condition in the river from the lake to Robey street than when you closed it? I do not see how simply a lock by itself is to be successfully operated in a river. It seems to me that much that has been said of a controlling works at this end, rests upon the assumption that the Drainage Canal is a *canal*, because it is called one: while as a fact, the whole thing, from the lake to Lockport, is a river. It is quite a different problem than to put a guard lock at the head of the canal, connecting it with a body of water that has a variable level.

Mr. Guthrie—I will suppose that a vessel has got jammed across the river and word is sent that the gates want to be closed. I have shown, or assumed—and I have made some figures to support it, that at Main street, where one vessel got jammed, 20 minutes would be ample time—and there could only be a difference of about 2.5 feet.

Mr. Seddon—But my question is, after you have shut this up, and after you have got the vessel out of the jam, then what will be the conditions in the Chicago River, when you open it?

Mr. Guthrie—We would necessarily have to increase that flow and let the water come to the proper slope. We would not open against a 4-foot head or an 8-foot head and let it go with a rush, but we would equalize that, just as they would have to do at the Lockport end with the bear-trap. It is in the same condition, in that respect, as the bear-trap, but this is always open except in case of an accident. Its normal condition is to pass through the guides of piling at the entrance, to pass through—just as the piles are driven and the guides made for ferry boats at New York or any other places on tide water, and they go through there when once entered, the same as passing through a bridge.

Mr. Warder—Mr. Seddon is speaking of the condition of the lock being closed. The boat has got out of the way—that will mean to open the wickets, so as to allow the water to flow through gradually.

Mr. Seddon—Yes.

Mr. Guthrie—For a very short period of time.

Mr. Seddon—When you start to shut this up, you have a distributed slope from the lake to Lockport, that is the thing that sticks your boats. When it has been closed, however, you break up this slope distribution; you stop the flow; you raise the section above the controlling works up to the lake level, and you drain out the section below down to the level of the bear-trap dam. Now, when you open this again, you throw what in the condition before was a distributed slope from the lake to Lockport, all into a concentrated slope from the lake to your controlling works.

Mr. Guthrie—If it takes you eight hours to back water up from the bear-trap dam to this point:, it will take more than eight hours to fill up the canal again—to let the gradual flow through this restricted area. It has taken on some occasions 12 to 14 hours to back the water up, to get relief. Now with this, we propose to get relief to the Washington street tunnel within one hour.

Mr. Seddon—But if, as a consequence of that, you are going to stick your boat again before it gets out of the river, or every other boat in the river, it is very poor relief. The question is, what is going to occur to get back to the old conditions of the flow in this river—back to the normal ones?

Mr. Guthrie—If we can maintain a uniform flow through this river of a mile an hour, and the pilots know that they have a current a mile an hour to navigate against, we shall probably hear very much less of the jamming of boats than now. But if we do not get caught, you can open your gates wide—the fall in the canal level would be so little that it would not be appreciable.

If it is at the Fort Wayne railroad bridge, where two or three vessels have been jammed, relief would come within a period of twenty minutes; if at Washington street tunnel, it will be an hour, or one-eighth part of the filling up of the canal.

It looks to me as if the difficulties you present will be more imaginary than real. It may sometimes have to be shut for 24 hours. It is true that the water would be distributed as you say, but it need not necessarily be a misfortune. Suppose a vessel is stranded on the Washington street tunnel; they ask for relief; the minute the water begins to raise, the tugs begin to pull, and then relief comes. Mr. Cooley figures it would give a hydraulic ram effect of 9 inches above the lake level.

Mr. Warder—Then the stopping of the flow would be so small and the lowering of the canal would be so little that you can open this again and come back to a normal condition without having an appreciable difference?

Mr. Guthrie—Yes.

Mr. Seddon—This is not a question that I feel prepared to discuss, because I have not given it the close study it requires; but certainly the first question to be thoroughly considered in this matter is the effect on this flow, understanding that the purpose of the Drainage Canal is not to hold, but to discharge the water.

As I remember it, with a flow of 300,000 cubic feet a minute there is a fall of about 2.5 feet from the lake to Robey street, and an additional fall of about 1.3 feet from there to Lockport. Now, even if you shut up the bear-trap immediately, the water which stands on this slope from Robey street to Lockport is going to level up, and in time will level up completely. Then you will have about 7-10 of a foot to add to the original fall from the lake to the lower end of this lock. You had originally 2½ feet fall from the lake to Robey street, which was a condition bad for the boats in the river. Now, when you open these gates again, instead of a fall from the lake to the controlling works of 2½ feet, you may have a fall of some 3¼ feet. And I say that if a 2½ foot fall was bad for a boat in the river, that 3¼ feet fall is worse.

I do not, of course, mean that the flow cannot be controlled at this end also; but to do so effectually may seriously decrease the efficiency of the Drainage Canal as a discharging channel. Further, to so control this flow will require something that is the equivalent of a movable dam, and then again, a lock for boats to pass from one level to the other; and in practice, I think it would be found difficult to continue these two distinct functions in the same structures as Mr. Guthrie proposes.

Mr. Guthrie—I think the gentleman has furnished a stronger argument than I have furnished for a controlling works. If he sees disaster in the shutting of these gates for an hour or two hours, for navigation, what would it be in such a change as we had in 1886, where the water rose 3 feet in half an hour, or in 1884, where it rose 2 feet in an hour or an hour and a half.

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CXI.

NORTHERN PACIFIC STANDARD BRIDGE PLANS.

By Ralph Modjeski, M. W. S. E.

About two and one-half years ago the writer was requested to revise the standard designs of steel bridges of the Northern Pacific Railway, and to complete the list by designing such spans as then remained uncompleted. At that time the railway company had a considerable number of these plans finished for a loading of two 116 ton locomotives preceded or followed, or preceded and followed, by a uniform load of 3,000 pounds. As the rolling stock was rapidly increasing in weight, it became necessary to increase the standard loading to two locomotives weighing 146 tons each, with a uniform load attached of 4,000 pounds per foot of track. The original plan was to modify the existing designs by simply changing the sections and increasing the strength of various connections, using as many of the old drawings as possible. It soon became evident that such a plan was impracticable and would consume more time than the final result, which could not be entirely satisfactory, would warrant. The reason for this is, as all know who have done similar work, that it is not enough to increase the sections but that lengths of cover plates, stringer and floorbeam connections, pin bearings and pin plates, sizes of pins, eyebar heads and a thousand other details must also be changed.

To change plans for a heavier loading can often be done in a fairly satisfactory manner without making new drawings, but only where the tonnage involved is comparatively small; that is to say, where a slight excess of metal in the sections or details would cost less than the labor of preparing entirely new plans. But when thousands of tons of bridge work may be built from a single drawing, too much care cannot be taken to have it as near perfection as to strength and economy as the shortcomings of the designer and of the present state of engineering knowledge will admit of. For this reason, and also for the reason that it became desirable to change some of the details of the old designs, an entirely new set of standards was prepared.

Before the writer became connected with this work, Mr. Geo. S.

Morison, to whom the plans were at first referred, recommended the adoption of 12 inch segmental rollers for expansion bearings, and also of the end floorbeam connection as now used in the new plans for pin-connected through spans. These recommendations were adopted, and included in the modifications.

The new set of standards consists in deck and through spans from 10 feet to 200 feet long, varying by 5 feet for spans below 100 feet, and by 10 feet for spans above 100 feet. The various kinds of structures are distributed as follows: I-beam spans from 10 to 30 feet, deck plate girders from 25 to 100 feet, through plate girders from 30 to 100 feet, deck lattice and pony lattice spans for 110 and 120 feet, deck and through pin-connected spans from 130 to 200 feet. To this list has also been added a typical design of a trestle tower 30 and 40 feet center to center of bents, and of deck plate girder spans for viaducts for spans from 30 to 70 feet, varying by 10 feet.

For each lattice and pin-connected deck span two types have been designed—one with end bearings near the top chord, and one with end bearings near the bottom chord.

The plans for all spans up to 120 feet have been made with all detail and are actually shop plans. The plans for pin-connected spans from 130 to 200 feet consist of strain sheets and general plans, with all details except rivet spacing and length of material. They therefore necessitate the preparation of working drawings by the contractors.

The drawings accompanying this paper show the character of the work and the typical details of all classes of structures, except the I-beam spans, which are very simple and do not present any remarkable features except that they are assembled by means of bolts and wrought steel separators and require no field riveting. The I-beam spans were prepared according to a typical span designed in the office of the Northern Pacific Railway. I shall only draw attention to the main features of these various classes of structures.

The practical limit of length of plate girders was taken at 100 feet for both through and deck. The flange angles and cover plates were alone considered in calculating the moment of resistance. This method had been used on the old set of standards, and, although I am of the opinion that the web should be taken into account, I decided that in the case of these standards it would be better not to do so in girders having spliced webs; in beams such as floorbeams and stringers, where the web is continuous, the latter has been included in the moment of resistance.

All stiffeners have been crimped over the flange angles except where they connect to cross frames or floorbeams. The expansion bearings for spans up to 65 feet have been made without rollers, and above these lengths with 12 inch segmental rollers. For spans from 50 feet to 65 feet a special hinge joint was designed, as shown on the plates representing the 60 feet spans. All shoes for hinge and roller bearings have been made of cast steel. Cast iron is only used for bed plates of fixed ends on spans having roller bearings and under plate girders 45 feet long and less. In the former they have been made of the same height as the rollers and rail plates combined, so as to make the height of masonry the same at both ends of the span.

It is customary to have all deck spans up to about 60 feet riveted together completely in the shop. Spans above that length, and all through spans, are shipped loose on account of difficulty in handling.

In through girders the floorbeam to girder connection was at first designed with both end angles riveted to the floorbeam. It was intended in that way to obtain the minimum amount of field riveting with the greatest simplicity of connection. That arrangement permitted the facing of the ends of floorbeams. There was, however, considerable difficulty in assembling the girders in the field, as the main girders had to be spread in order to place the floor system. It was, therefore, found preferable to rivet one of the end connecting angles to the main girders and ship the other one loose. The drawings were changed accordingly.

There is nothing remarkable about the lattice girders except, perhaps, that the design of the pony through lattice has been considerably simplified from the old design which was published some time ago in *Engineering News* (Jan. 5, 1899).

The writer has also designed a typical riveted through span with overhead bracing. For a 110 foot span this design is about 19,000 pounds lighter than the corresponding pony through span, but there being more field riveting to be done in the former, and, beside, the absence of overhead bracing being always a desirable feature, the chief engineer of the Northern Pacific Railway pronounced himself in favor of the pony design.

In the through pin spans the top lateral bracing was made adjustable for two reasons: First, because it is lighter, the stiff bracing requiring considerable excess of metal; and, second, because the top chord can be thoroughly lined up by adjusting the rods. The bottom lateral bracing has been made of angles riveted to the bottom flanges of stringers by means of lugs. The stringer bracing consists of diagonal angles riveted to the top flanges and one cross frame at the center of each panel. In the deck spans this bracing is similar, except that no intermediate cross frames have been provided, the bottom flanges of stringers being rigidly held by the laterals.

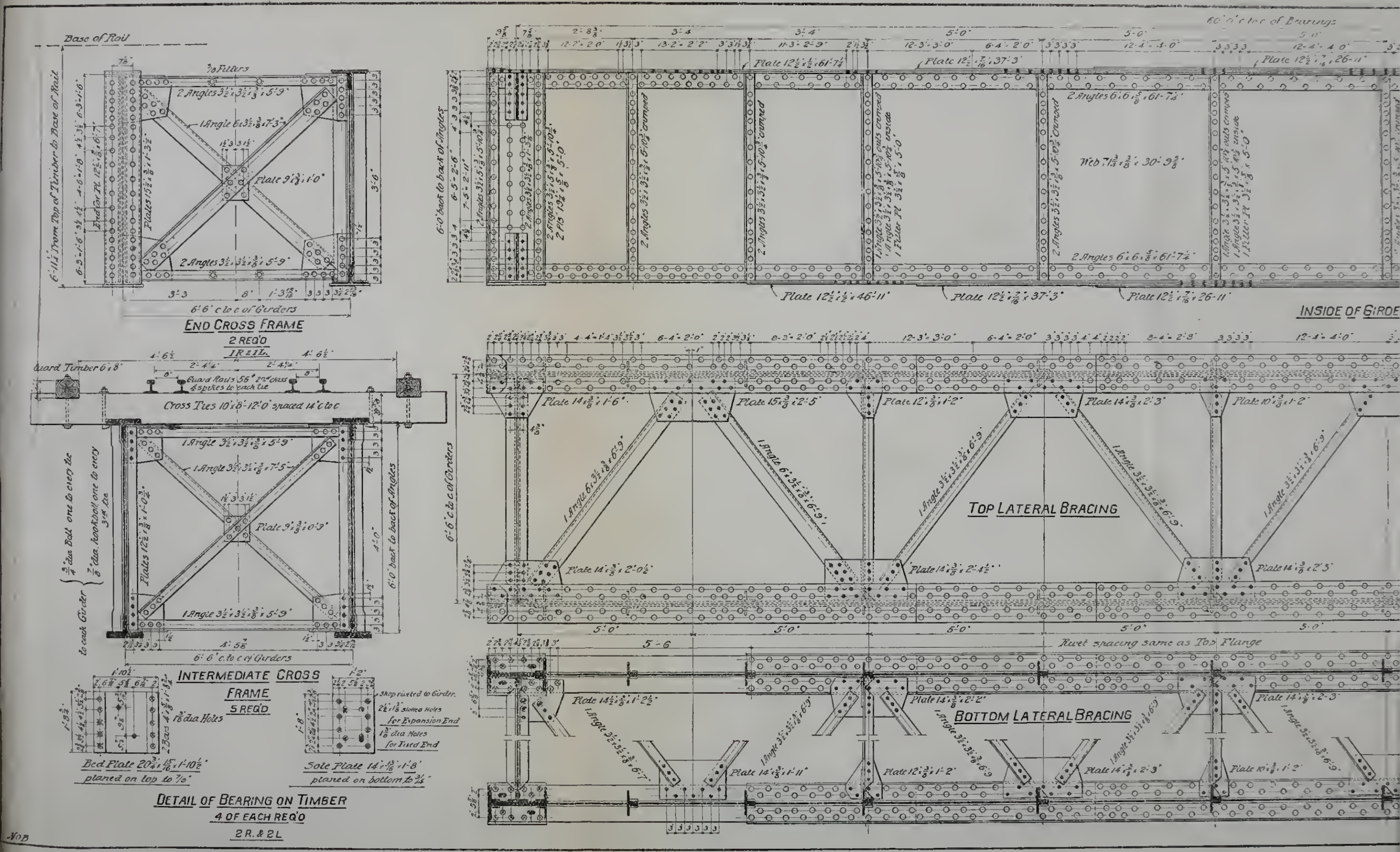
The 130 foot through span has a stiff bottom chord throughout. The longer spans have the usual stiff bottom chord in the two end panels.

In the pin-connected deck spans the bottom lateral system is left out. Each pair of vertical posts has its sway frame, and the wind and vibration stresses are carried down the inclined end posts by means of a very strong cross frame. A somewhat unusual connection has been designed for the top lateral angles:—the lateral plate is riveted to the top chord, the bottom flange of the stringer and the top flange of the floorbeam.

In all pin spans the balancing of the compression chords and end posts having cover plates is done by using four angles, two inside and two outside at the lower flange. The lacing attaches to the inside angles wherever such are used.

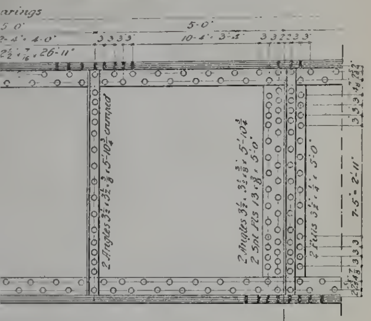
All end shoes in all spans are of cast steel. The rollers are of forged or cast steel and are of uniform cross section for all bearings.

I have attached to this paper a diagram of weights. The full lines show weights of the present standards. The dotted line shows the weights of some through pin-connected spans calculated for the same loading and actually built. These spans are the result of modifying the original Northern Pacific standards, which were designed for a lighter load, to carry the present standard loading. This was done in a few instances before the present standards were completed, and shows what can be done by careful designing. In the case of the 200 foot span, the original design, modified by a

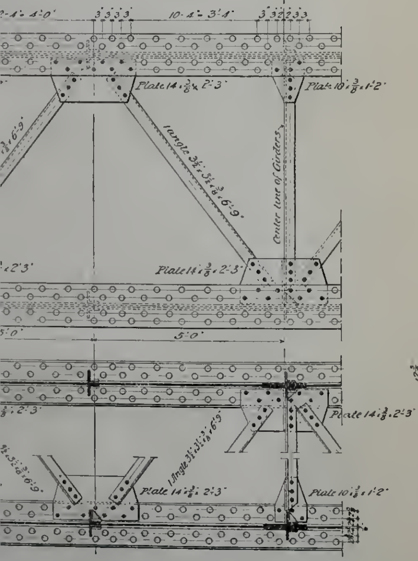

Base of Rail
7/8 Fillers
2 Angles 3½ x 3½ x 3/8 x 5'-9"
1 Angle 6 x 3½ x 3/8 x 7'-3"
Plate 9 x 3/8 x 1'-0"
6'-11¼" From Top of Timber to Base of Rail
6'-6" c to c of Girders
END CROSS FRAME
2 REQ'D
1R & 1L
Guard Timber 6 x 8"
Guard Rails 56# 2nd class
4 spikes to each tie
Cross Ties 10 x 8 - 12'-0" spaced 14" c to c
1 Angle 3½ x 3½ x 3/8 x 5'-9"
1 Angle 3½ x 3½ x 3/8 x 7'-5"
Plate 9 x 3/8 x 0'-9"
Plates 12½ x 3/8 x 1'-0¾"
¾" dia Bolt one to every tie
7/8" dia hook bolt one to every 3rd tie
to each Girder
6'-0" back to back of Angles
INTERMEDIATE CROSS FRAME
5 REQ'D
1⅛" dia Holes
Bed Plate 20¾ x 15/16 x 1'-10½"
planed on top to 7/8"
Sole Plate 14 x 13/16 x 1'-8"
planed on bottom to ¾"
Shop riveted to Girder
2¼ x 1⅛ slotted Holes for Expansion End
1⅛" dia Holes for Fixed End
DETAIL OF BEARING ON TIMBER
4 OF EACH REQ'D
2R & 2L
60'-0" c to c of Bearings
Plate 12½ x ½ x 61'-7¼"
Plate 12½ x 7/16 x 37'-3"
Plate 12½ x 7/16 x 26-11"
2 Angles 6 x 6 x 5/8 x 61'-7¼"
Web 71¾ x 3/8 x 30'-9⅜"
Plate 12½ x ½ x 46'-11"
INSIDE OF GIRDER
Plate 14 x 3/8 x 1'-6"
Plate 15 x 3/8 x 2'-5"
Plate 12 x 3/8 x 1'-2"
Plate 14 x 3/8 x 2'-3"
Plate 10 x 3/8 x 1'-2"
1 Angle 6 x 3½ x 3/8 x 6'-9"
1 Angle 3½ x 3½ x 3/8 x 6'-9"
TOP LATERAL BRACING
6'-6" c to c of Girders
Plate 14 x 3/8 x 2'-0½"
Plate 14 x 3/8 x 2'-4½"
Plate 14 x 3/8 x 2'-3"
Rivet spacing same as Top Flange
Plate 14½ x 3/8 x 1'-2½"
Plate 14 x 3/8 x 2'-2"
BOTTOM LATERAL BRACING
1 Angle 3½ x 3½ x 3/8 x 6'-7"
Plate 14 x 3/8 x 1'-11"
Plate 12 x 3/8 x 1'-2"
Plate 14 x 3/8 x 2'-3"
Plate 10 x 3/8 x 1'-2"
1 Angle 3½ x 3½ x 3/8 x 6'-9"
NOB

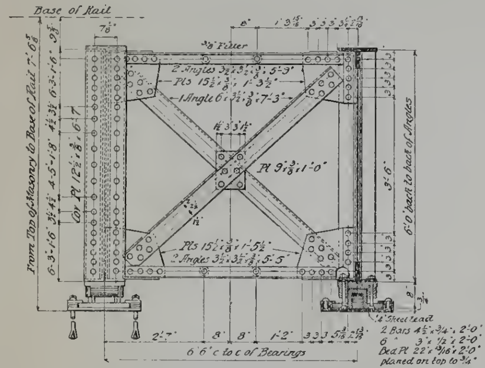
R-10-311.

COMPLETE SET: R-10-311 AND R-10-276.

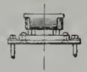


NSIDE OF GIRDER

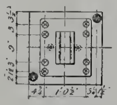




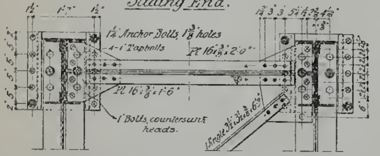
Sliding End.



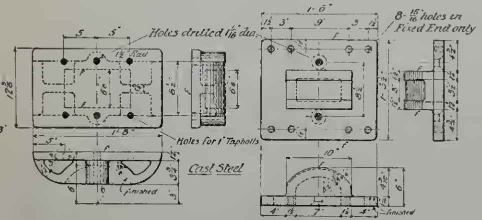
Fixed End Bearing.



Bed Pl 22 × 1⅜ × 1'-10"
planed on top to 1¼
2 Req'd.
1R & 1L.


1¼" Anchor Bolts, 1⅜ holes
4-1" Tapbolts
Pl 16 × ⅜ × 2'-0"
Pl 16 × ⅜ × 1'-6"
1" Bolts, countersunk heads.
1 Angle 3½ × 3½ × ⅜ × 6'-9"

END CROSS FRAME AND LATERAL CONNECTIONS.
FOR BEARING ON MASONRY.



DETAIL OF CASTINGS FOR BEARING ON MASONRY.
4 OF EACH REQ'D.

BILL OF TRACK MATERIAL.
FOR ONE SPAN.

Material	No. req'd	Size	Length	Mark
Ties	53	10 × 8	12'0	
Guard Timber	2	6 × 8	62'0	
Floor Bolts	106	¾" dia	1'-4½	B ☐
Hookbolts	38	⅞" dia	1'-0"	C ☐
☐ see Standard Drawing R-10-276				

Note.

Two different Details are shown for the End Bearings. one for Bearing on Timber and one on Masonry. In ordering, state which is wanted.

Notes.

All Material to be Medium Steel (except where noted)
All Rivets to be ⅞" dia and Soft Steel
All Rivet holes to be punched 11/16" and reamed to 15/16" dia
All Stiffeners to have a driving fit between Flange angles
In size of angles, first figure indicates leg of angle shown.
If convenient for unloading in field, shop rivet lateral angles and Cross frames to Girders.

Span calculated for 2- 146 ton Engines, preceded and followed by 4000 lbs per foot
End Shear R L + 12% Impact. = 106 658 lbs
D L = 19 500 "
Total = 126 158
Max. Mom from R L + 12% I = 1410650 ft lbs
" " " D L = 292500 " "
Allowable Unit Stress R L. = 10500 lbs per sq inch
" " " D L. = 18000 " " " "
Effective Depth 5.8 feet.

N.P.R'Y.

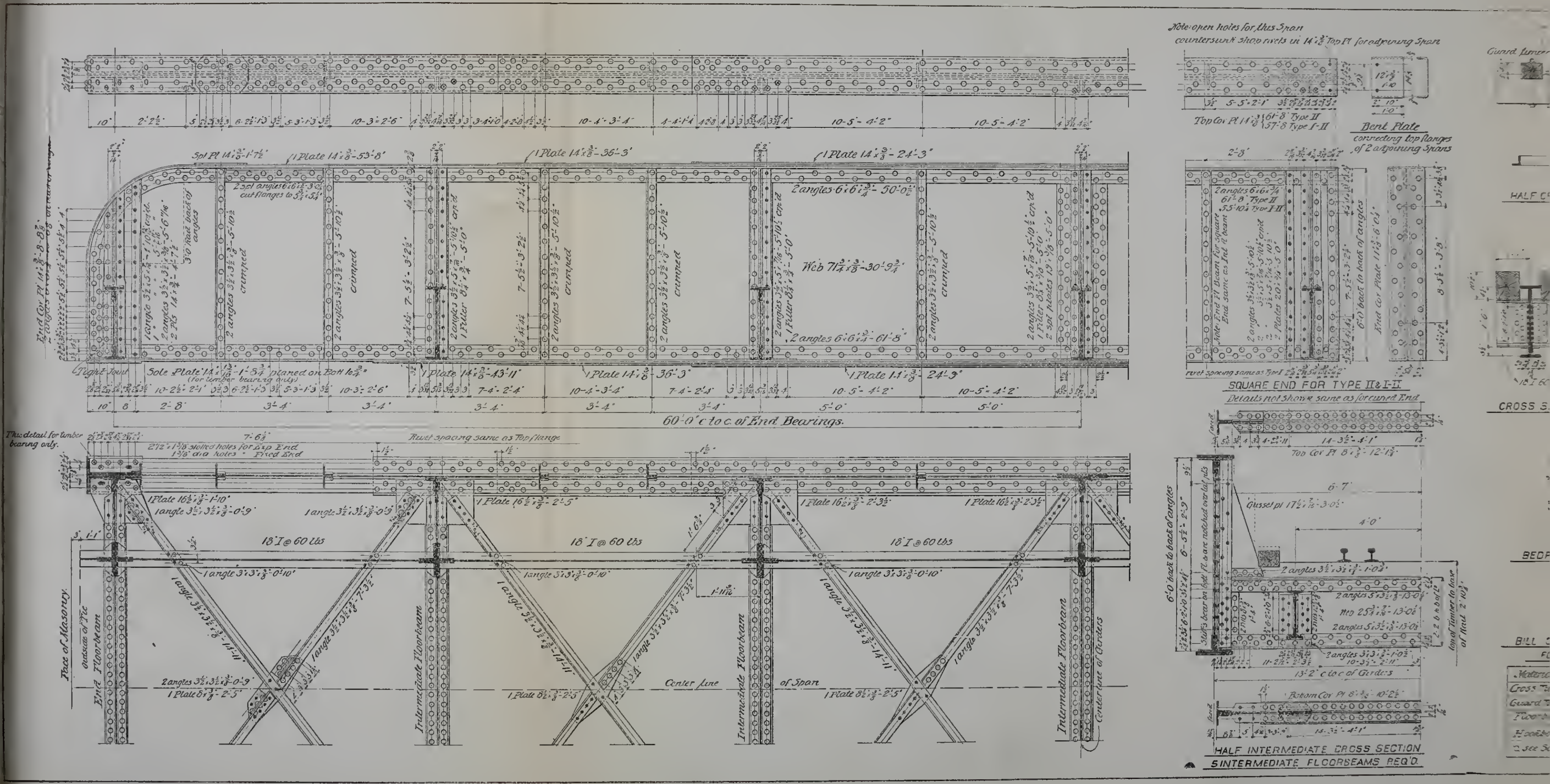
STANDARD PLAN.

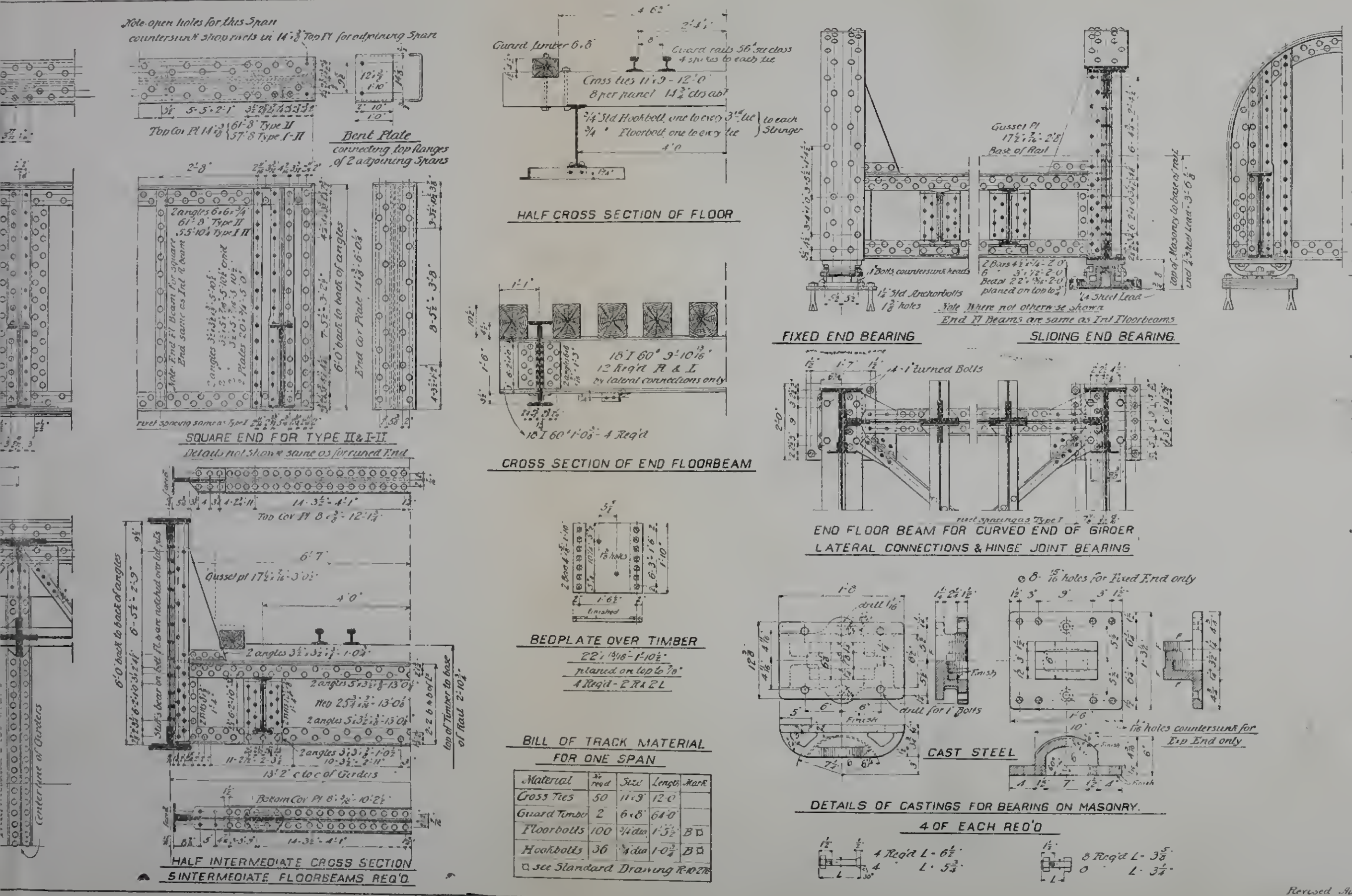
60 FT. DECK PLATE GIRDER.

SCALE ¾" = 1'

Approved
General Manager
Chief Engineer

RALPH MODJESKI
Civil Engineer
Monadnock Bldg
Chicago
SEPT·1898


Note: open holes for this Span countersunk shop rivets in 14 x 3/8 Top Pl for adjoining Span
Top Cov Pl 14 x 3/8 {61-8 Type II, 57-8 Type I-II}
Bent Plate connecting top flanges of 2 adjoining Spans
Guard Timber
Spl Pl 14 x 3/8 - 1-7 1/2
1 Plate 14 x 3/8 - 53-8
1 Plate 14 x 3/8 - 36-3
1 Plate 14 x 3/8 - 24-3
End Cov Pl 14 x 3/8 - 8-8
2 Spl angles 6 x 6 x 3/4 - 3-0 cut flanges to 5 1/4 x 5 1/4
2 angles 6 x 6 x 3/4 - 50-0 1/2
Web 71 1/4 x 3/8 - 30-9 3/4
2 angles 6 x 6 x 3/4 - 61-8
2 angles 3 1/2 x 3 1/2 x 3/8 - 5-10 1/2 crimped
Sole Plate 14 x 1 1/2 - 1-8 3/4 planed on Bott to 1 3/8 (for timber bearing only)
Tight Joint
1 Plate 14 x 3/8 - 43-11
1 Plate 14 x 3/8 - 36-3
1 Plate 14 x 3/8 - 24-3
60-0 c to c of End Bearings.
This detail for timber bearing only.
2 1/2 x 1 7/8 slotted holes for Exp End, 1 3/8 dia holes - Fixed End
Rivet spacing same as Top flange
1 Plate 16 1/2 x 3/8 - 1-10
1 angle 3 1/2 x 3 1/2 x 3/8 - 0-9
1 Plate 16 1/2 x 3/8 - 2-5
1 Plate 16 1/2 x 3/8 - 2-3 1/2
18 I @ 60 lbs
1 angle 3 x 3 x 3/8 - 0-10
1 angle 3 1/2 x 3 1/2 x 3/8 - 14-11
1 angle 3 1/2 x 3 1/2 x 3/8 - 7-3 1/2
2 angles 3 1/2 x 3 1/2 x 3/8 - 0-9
1 Plate 8 1/2 x 3/8 - 2-5
Face of Masonry
outside of Pl
End Floorbeam
Intermediate Floorbeam
Center Line of Span
Centerline of Girders
SQUARE END FOR TYPE II & I-II
Details not shown same as for curved End
2 angles 6 x 6 x 3/4: 61-8 Type II, 55-10 1/2 Type I-II
Note: End Fl Beam for square End same as Int Fl beam
6-0 back to back of angles
End Cov Plate 14 x 3/8 - 6-0 1/2
rivet spacing same as Type I
Top Cov Pl 8 x 3/8 - 12-1 1/2
Gusset pl 17 1/2 x 7/16 - 3-0 1/2
Stiff's bear on Bott Fl & are notched over lat pls
2 angles 3 1/2 x 3 1/2 x 3/8 - 1-0 3/4
2 angles 5 x 3 1/2 x 3/8 - 13-0 1/4
Web 25 3/4 x 7/16 - 13-0 1/4
2 angles 5 x 3 1/2 x 3/8 - 13-0 1/4
2 angles 3 x 3 x 3/8 - 1-0 1/2
top of Timber to base of Rail 2-10 3/4
13-2 c to c of Girders
Bottom Cov Pl 8 x 3/8 - 10-2 1/2
HALF INTERMEDIATE CROSS SECTION
5 INTERMEDIATE FLOORBEAMS REQ'D.
HALF C
CROSS S
BEDP
BILL
Material
Cross T
Guard T
Floorb
Hookb
2 see S


Note-open holes for this Span countersunk shop rivets in 14·⅜ Top Pl for adjoining Span
Top Cov Pl 14·⅜ 61·8 Type II / 57·8 Type I-II
Bent Plate
connecting top flanges of 2 adjoining Spans
SQUARE END FOR TYPE II & I-II.
Details not shown same as for curved End
Top Cov Pl 8·⅜·12·1¼
Gusset pl 17½·⅞·3·0½
2 angles 3½·3½·⅞·1·0½
2 angles 5·3½·⅞·13·0⅛
Web 25½·⅞·13·0⅝
2 angles 5·3½·⅞·13·0⅛
13·2 c to c of Girders
Bottom Cov Pl 8·⅜·10·2½
Centerline of Girders
HALF INTERMEDIATE CROSS SECTION
5 INTERMEDIATE FLOORBEAMS REQ'D.
Guard Timber 6·8
Guard rails 56# see class 4 spikes to each tie
Cross ties 11·9·12·0
8 per panel 14½ cts abt
¾ Std Hookbolt one to every 3rd tie
¾ Floorbolt one to every tie
to each Stringer
HALF CROSS SECTION OF FLOOR
18 I 60# 9·10 13/16
12 Req'd R & L
by lateral connections only
18 I 60# 1·0½ - 4 Req'd
CROSS SECTION OF END FLOORBEAM
1⅞ holes
Finished
BEDPLATE OVER TIMBER
22·13/16·1·10½
planed on top to ⅞
4 Req'd - 2 R & 2 L
Gusset Pl 17½·⅞·2·8
Base of Rail
1 Bolts countersunk heads
1¼ Std Anchorbolts
1⅜ holes
2 Bars 4½·¼·2·0
6 3·½·2·0
Bedpl 22·1⅜·2·0
planed on top to ¾
¼ Sheet Lead
Note Where not otherwise shown End Fl Beams are same as Int Floorbeams
top of Masonry to base of rail
FIXED END BEARING
SLIDING END BEARING
4-1 turned Bolts
END FLOOR BEAM FOR CURVED END OF GIRDER
LATERAL CONNECTIONS & HINGE JOINT BEARING
6-15/16 holes for Fixed End only
drill 1/16
drill for 1 Bolts
Finish
CAST STEEL
1⅞ holes countersunk for Exp End only
DETAILS OF CASTINGS FOR BEARING ON MASONRY.
4 OF EACH REQ'D
4 Req'd L - 6½
4 L - 5¾
8 Req'd L - 3⅜
8 L - 3¼

BILL OF TRACK MATERIAL
FOR ONE SPAN

Material	No. reqd	Size	Length	Mark
Cross Ties	50	11·9	12·0	
Guard Timber	2	6·8	64·0	
Floorbolts	100	¾ dia	1·5½	B ☐
Hookbolts	36	¾ dia	1·0¾	B ☐
☐ see Standard Drawing R-10-276				

R-10-354.
COMPLETE SET
R-10-354
R-10-276.

Note: Two different Details are shown for the End Bearings
One for bearing on Timber and one on Masonry
In ordering state which is wanted

Notes

All Material to be Medium Steel (except where noted)
All Rivets to be ⅞ dia and Soft Steel All bolts soft steel.
All Rivetholes to be punched 11/16 and reamed to 15/16 dia
All Shop riveted stiffeners to have a driving fit between flange angles
In Size of angles first figure indicates leg of angle shown
Span calculated for 2-146 ton Engines preceded and followed by 4000 lbs per foot

Main Girders

End Shear R L + 12% Impact	=	105650 lbs
" " D L	=	23850 "
Total	=	129500 "
Max Mom from R L + 12% Impact	=	1428000 ft lbs
" " " D L	=	358000 " "
Effective Depth 5 8 feet		

Floor Beams

Total End Shear	=	59800 lbs
Max Mom from R L + 21 % I	=	107000 ft lbs
" " " D L	=	10400 "

Stringers

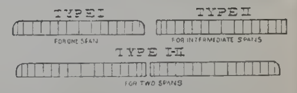
Total End Shear	=	46100 lbs
Max Mom. from R L + 23 % I	=	76900 ft lbs
" " " D L	=	4000 " "
Allowable Unit Stress R L	=	10500 lbs per sq inch
" " " D L	=	18000 " " " "

Est Weight one span complete with floorbolts Timber Bearing - 68600
" " " " " " " Masonry " - 69900

N.P.R'Y.

STANDARD PLAN.

60FT. THROUGH PLATE GIRDER.



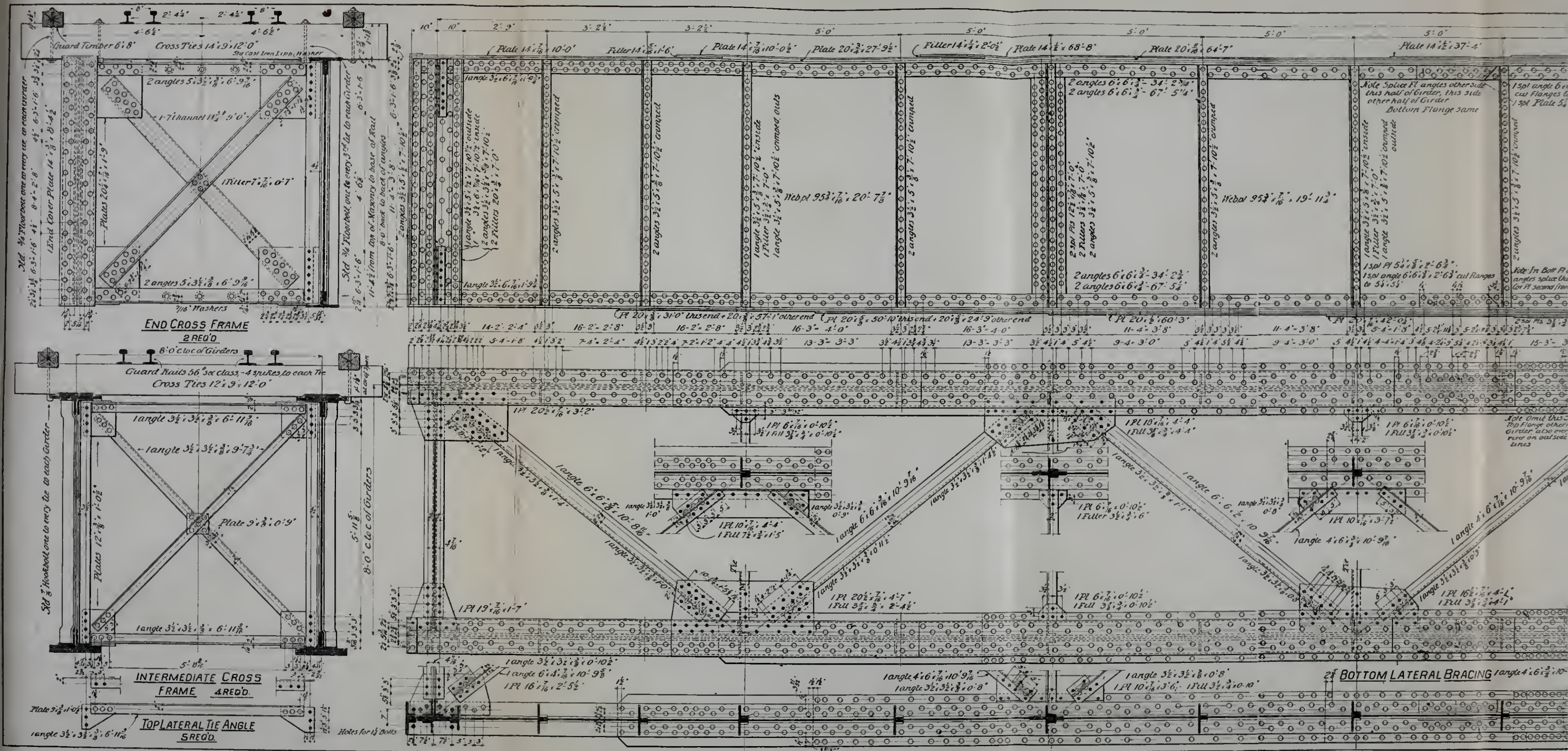
SCALE ¾"=1'

Approved
Second Vice President

Chief Engineer

RALPH MODJESKI
CIVIL ENGINEER
Monadnock Bldg
CHICAGO
DEC 30, 1898

Revised Aug 1900

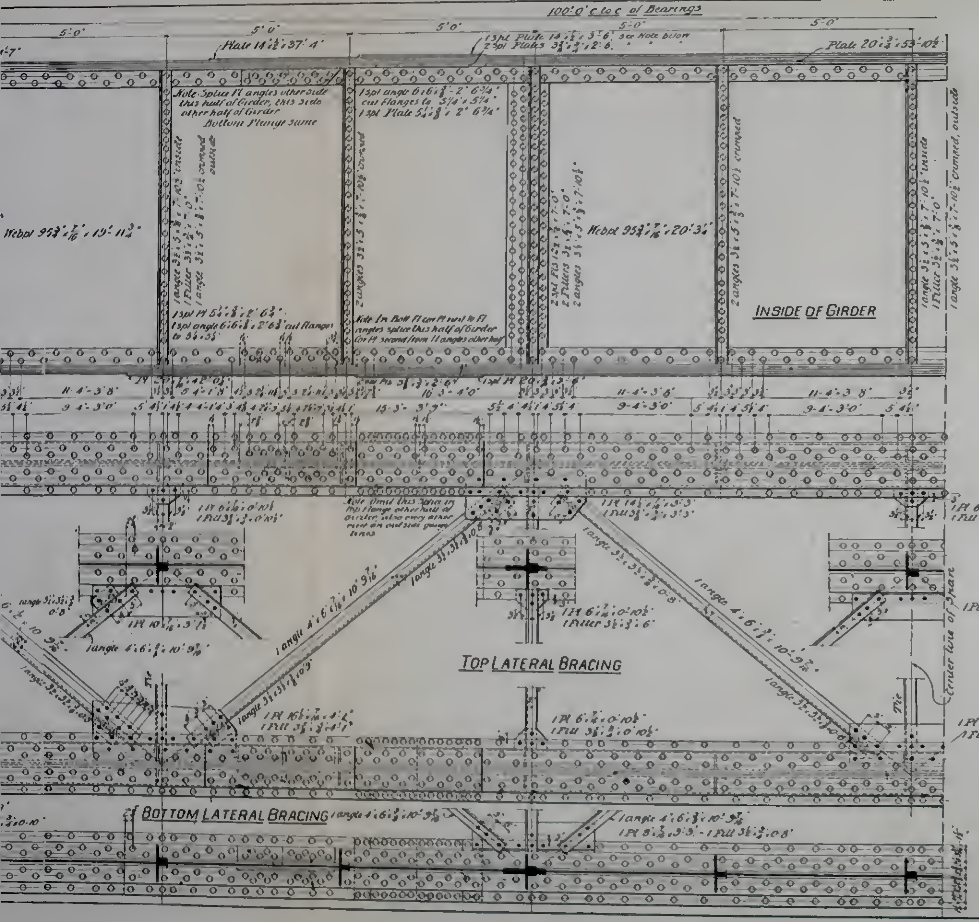


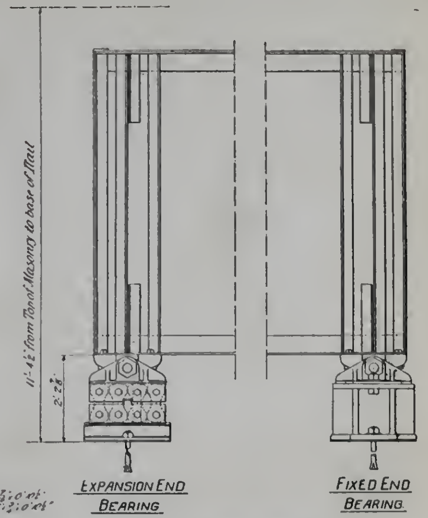
END CROSS FRAME
2 REQ'D
Guard Timber 6"x8"
Cross Ties 14"x9"x12'-0"
2 angles 5"x3½"x⅜"x6'-9 9/16"
1-7" channel 11¾"x9'-0"
1 Filler 7"x7/16"x0'-7"
7/16" Washers
INTERMEDIATE CROSS FRAME 4 REQ'D
8'-0" c to c of Girders
Guard Rails 56# 3rd class, 4 spikes to each Tie
Cross Ties 12"x9"x12'-0"
1 angle 3½"x3½"x⅜"x6'-11 7/8"
1 angle 3½"x3½"x⅜"x9'-7¾"
Plate 9"x⅜"x0'-9"
Plates 12"x⅜"x1'-0½"
8'-0" c to c of Girders
TOP LATERAL TIE ANGLE 5 REQ'D
1 angle 3½"x3½"x⅜"x6'-11 7/8"
Holes for ⅞" Bolts
Plate 14"x7/16"x10'-0"
Filler 14"x5/16"x1'-6"
Plate 14"x7/16"x10'-0½"
Plate 20"x⅜"x27'-9½"
Filler 14"x¼"x2'-0½"
Plate 14"x½"x68'-8"
Plate 20"x9/16"x64'-7"
Plate 14"x½"x37'-4"
Web pl 95¾"x7/16"x20'-7⅞"
Web pl 95¾"x7/16"x19'-11¾"
2 angles 6"x6"x¾"-34'-2¾"
2 angles 6"x6"x¾"-67'-5¼"
Note Splice Pl angles other side this half of Girder, this side other half of Girder
Bottom Flange same
1 Pl 20"x7/16"x3'-2"
1 Pl 19"x7/16"x1'-7"
1 angle 6"x6"x⅝"x10'-8 11/16"
1 angle 6"x6"x9/16"x10'-9 11/16"
1 angle 4"x6"x7/16"x10'-9 9/16"
1 Pl 10"x7/16"x4'-4"
1 Pl 20½"x7/16"x4'-7"
1 Pl 18"x7/16"x4'-4"
1 Pl 16"x7/16"x2'-5½"
BOTTOM LATERAL BRACING

Western Society of Engineers.
Vol. VI, No. 1.—Fig. 3.
Modjeski—Northern Pacific Standard Bridge Plans.

R-10-320.

COMPLETE SET
R-10-320
R-10-276
R-10-381.





EXPANSION END BEARING

FIXED END BEARING

BILL OF TRACK MATERIAL
FOR ONE SPAN

Material	No. req'd	Size	Length	Mark
Cross Ties	30	14 x 9	12'0"	
Cross Ties	57	12 x 9	12'0"	
Guard Timber	2	6 x 8	102'0"	
Floorbolts	36	3/4" dia	1'-8 1/2"	B ☐
Floor Bolt with I and Washer at C.S. Loop Plate	14	3/4" dia	1'-5"	B ☐
Hookbolts	138	5/8" dia	1'-8"	C ☐
☐ see Standard Drawing R-10-276				

Notes.

All Material to be Medium Steel
All Rivets to be 7/8" dia and Soft Steel
All Rivet holes to be punched 11/16" and reamed to 15/16" dia
All Stiffeners to have a driving fit between flange angles
In size of angles first figure indicates leg of angle shown.
Webplates to be spliced so as to produce a camber of 1 inch at center of Span.
Cross Ties to be framed so as to leave a camber of 1/2 inch in finished unloaded Span.
Span calculated for 2-146 ton Engines, preceded and followed by 4000 lbs. per foot
End Shear R.L. + 8% Impact – 154 980 lbs
" " D.L. – 43 750 "
Total – 198 730 "
Max Mom from R.L. + 8% I – 3 369 600 ft lbs
" " " D.L. – 1 092 500 " "
Allowable Unit Stress R.L. – 10 500 lbs per sq inch
" " " D.L. – 18 000 " " " "
Effective Depth – 7.8 feet
Est Weight one span complete with floorbolts – 135 900

N.P.R'Y.

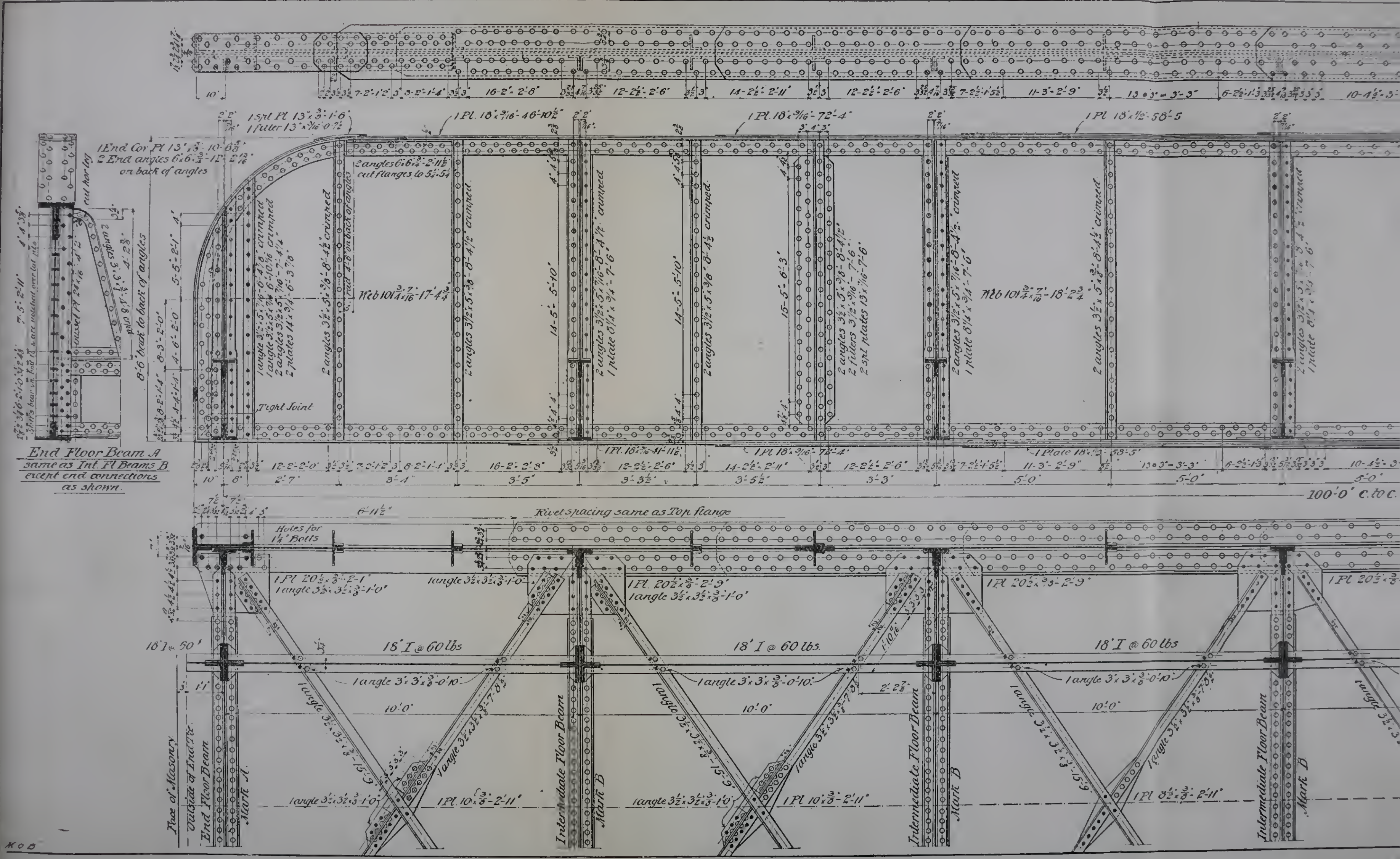
STANDARD PLAN.

100 FT. DECK PLATE GIRDER.

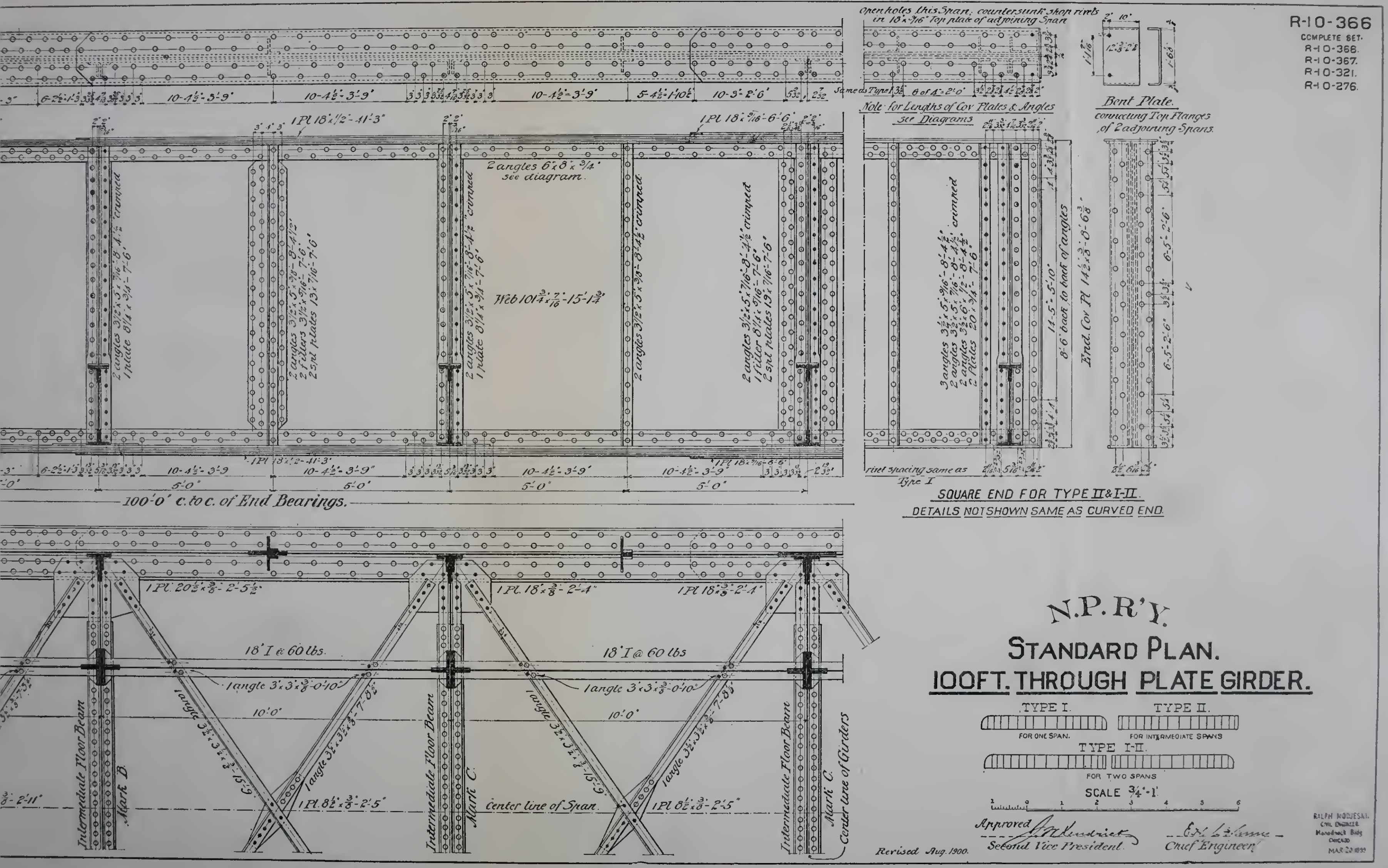
SCALE 3/4" - 1'

Approved
General Manager
Chief Engineer

RALPH MODJESKI
CIVIL ENGINEER
Monadnock Bldg
CHICAGO
OCT 26 1898


1 End Cov Pl 13" 3/8 - 10-6 3/8
2 End angles 6x6x3/4 - 12 - 2 13/16
on back of angles
cut for leg
8'-6" back to back of angles
End Floor Beam A
same as Int Fl Beams B
except end connections
as shown.
1 spl Pl 13" x 3/8 - 1-6
1 filler 13" x 9/16 - 0-7 1/2
1 Pl 18" x 9/16 - 46'-10 1/2"
1 Pl 18" x 9/16 - 72'-4"
1 Pl 18" x 1/2 - 58'-5
2 angles 6x6x3/4 - 2-11 1/2
cut flanges to 5 1/4 - 5 1/4
Web 101 1/4 x 7/16 - 17'-4 3/4
Web 101 1/4 x 7/16 - 18'-2 3/4
Tight Joint
2 angles 3 1/2 x 5 x 3/8 - 8'-4 1/2 crimped
14-5" - 5'-10"
15-5" - 6'-3"
2 angles 3 1/2 x 5 x 7/16 - 8'-4 1/2
2 fillers 3 1/2 x 9/16 - 7'-6"
2 spl plates 13 x 7/16 - 7'-6"
1 plate 8 1/4 x 3/4 - 7'-6"
1 Pl 18 x 9/16 - 41'-11 1/2
1 Pl 18" x 9/16 - 72'-4"
1 Plate 18 x 1/2 - 58'-5"
10" 8" 2'-7" 3'-1" 3'-5" 3'-3 1/2" 3'-5 1/2" 3'-3" 5'-0" 5'-0" 5'-0"
100'-0" c. to c.
Rivet spacing same as Top flange
6'-11 1/2"
Holes for 1 1/4" Bolts
1 Pl 20 1/2 x 3/8 - 2-1"
1 angle 3 1/2 x 3 1/2 x 3/8 - 1-0"
1 Pl 20 1/2 x 3/8 - 2'-9"
1 angle 3 1/2 x 3 1/2 x 3/8 - 1'-0"
18" I @ 60 lbs
1 angle 3" x 3" x 3/8 - 0'-10"
10'-0"
2'-2 7/8"
1 angle 3 1/2 x 3 1/2 x 3/8 - 15'-9
1 angle 3 1/2 x 3 1/2 x 3/8 - 7'-8 1/2
1 Pl 10 x 3/8 - 2'-11"
1 Pl 8 1/2 x 3/8 - 2'-11"
Face of Masonry
Outside of End Tie
End Floor Beam
Mark A
Intermediate Floor Beam
Mark B
K O B

WESTERN SOCIETY OF ENGINEERS.
Vol. VI. No. 1.—FIG. 4.
Modjeski—Northern Pacific Standard Bridge Plans.


R-10-366
COMPLETE SET.
R-10-366.
R-10-367.
R-10-321.
R-10-276.
Open holes this Span; countersunk shop rivets in 18"x 7/16" Top plate of adjoining Span
Bent Plate connecting Top Flanges of 2 adjoining Spans.
Note: for Lengths of Cov. Plates & Angles see Diagrams
1 Pl. 18"x 1/2"- 41'-3"
1 Pl. 18"x 9/16"- 6'-6"
2 angles 6"x 8"x 3/4" see diagram.
Web 101 3/4"x 7/16"-15'-1 3/4"
2 angles 3 1/2"x 5"x 7/16"-8'-4 1/2" crimped
1 plate 8 1/4"x 3/4"-7'-6"
2 angles 3 1/2"x 5"x 3/8"-8'-4 1/2" crimped
End Cov. Pl 14 1/2"x 3/8"-0'-6 3/8"
8'-6" back to back of angles
riv. spacing same as Type I
SQUARE END FOR TYPE II & I-II.
DETAILS NOT SHOWN SAME AS CURVED END.
100'-0" c. to c. of End Bearings.
5'-0"
1 Pl. 20 1/2"x 3/8"- 2'-5 1/2"
1 Pl. 18"x 3/8"- 2'-4"
18" I @ 60 lbs.
1 angle 3"x 3"x 3/8"-0'-10"
1 angle 3 1/2"x 3 1/2"x 3/8"-15'-9"
1 angle 3 1/2"x 3 1/2"x 3/8"-7'-8 3/4"
1 Pl. 8 1/2"x 3/8"- 2'-5"
10'-0"
Intermediate Floor Beam
Mark B.
Mark C.
Center line of Span.
Center line of Girders

N.P.R'Y.

STANDARD PLAN.

100FT. THROUGH PLATE GIRDER.

TYPE I.
FOR ONE SPAN.

TYPE II.
FOR INTERMEDIATE SPANS

TYPE I-II.
FOR TWO SPANS

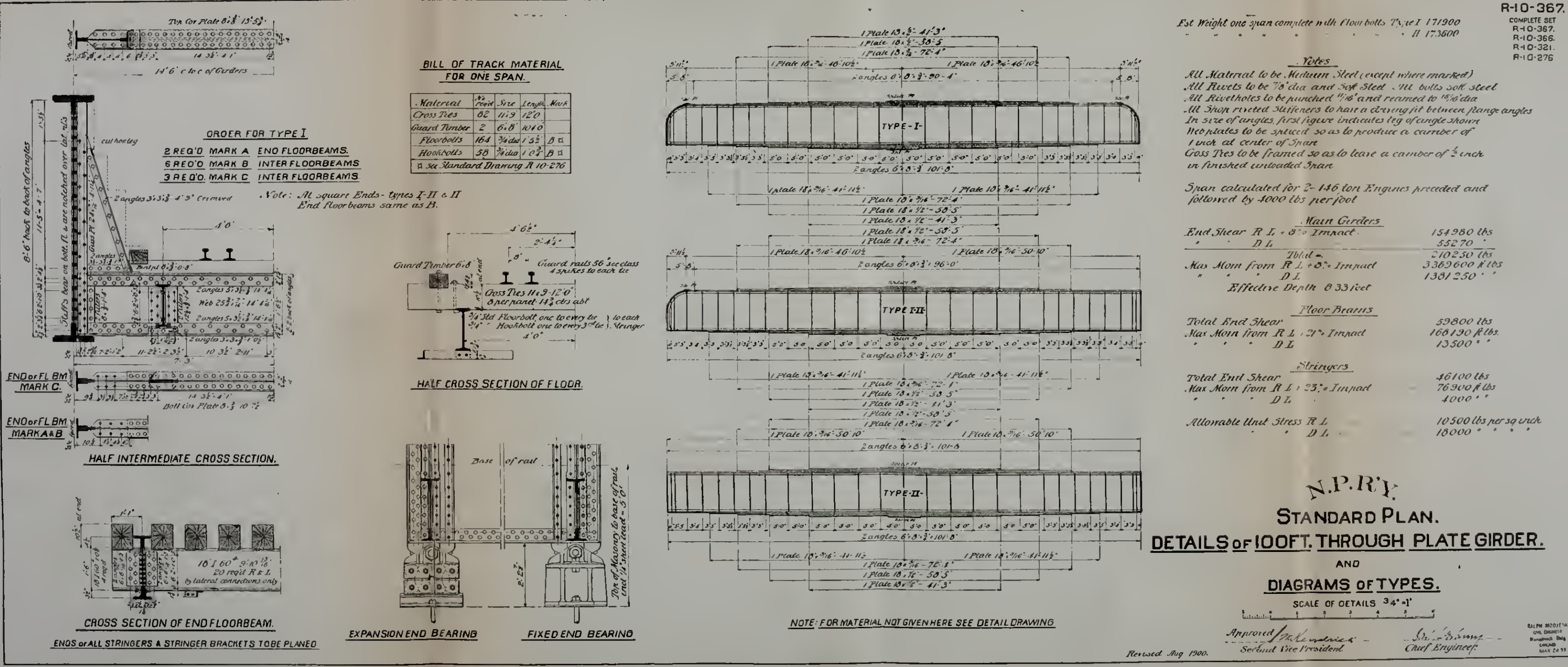
SCALE 3/4"-1'

Approved J. W. Kendrick
Second Vice President.

E. H. McHenry
Chief Engineer.

Revised Aug. 1900.

RALPH MODJESKI
CIVIL ENGINEER
Monadnock Bldg
CHICAGO
MAR 20 1899


R-10-367.
COMPLETE SET
R-10-367.
R-10-366.
R-10-321.
R-10-276
Top Cov Plate
14'6" c to c of Girders
cut hor leg
2 angles 3½·3½·⅜·4'9" Crimped
8'6" back to back of angles
4'0"
Web
2 angles
END OF FL BM MARK C.
Bolt Cov Plate
END OF FL BM MARK A & B
HALF INTERMEDIATE CROSS SECTION.
4'6½"
2'4¼"
Guard Timber 6·8
Guard rails 56 see class 4 spikes to each tie
Cross Ties 11·9·12'0" 8 per panel 14¾ ctrs abt
¾ Std Floorbolt one to every tie
¾" Hookbolt one to every 3rd tie
to each Stringer
4'0"
HALF CROSS SECTION OF FLOOR.
TYPE-I-
TYPE I-II
TYPE-II-
1 Plate 18·½·41'3"
1 Plate 18·½·58'5
1 Plate 18·9/16·72'4"
1 Plate 18·9/16·46'10½
2 angles 6·6·¾·90-4"
2 angles 6·6·¾·101'8"
1 Plate 18·9/16·41'11½
2 angles 6·6·¾·96'0"
1 Plate 18·9/16·50'10"
5'0"
3'11½
5'8"
10 I 60# 9'10 13/16 20 reqd R & L
Base of rail
Top of Masonry to base of rail and ¼" sheet lead - 5'0"
2'2⅞"
CROSS SECTION OF END FLOORBEAM.
ENDS OF ALL STRINGERS & STRINGER BRACKETS TO BE PLANED
EXPANSION END BEARING
FIXED END BEARING
NOTE: FOR MATERIAL NOT GIVEN HERE SEE DETAIL DRAWING

ORDER FOR TYPE I

2 REQ'D MARK A END FLOORBEAMS.
6 REQ'D MARK B INTER FLOORBEAMS
3 REQ'D. MARK C INTER FLOORBEAMS

Note: At square Ends - types I-II & II
End floorbeams same as B.

BILL OF TRACK MATERIAL FOR ONE SPAN.

Material	No reqd	Size	Length	Mark
Cross Ties	82	11·9	12'0	
Guard Timber	2	6·8	101'0	
Floorbolts	164	¾ dia	1'5½	B ☐
Hookbolts	58	¾ dia	1'0¾	B ☐
☐ See Standard Drawing R 10-276				

Est Weight one span complete with floor bolts Type I 171900
" " " " " " " " II 173600

Notes

All Material to be Medium Steel (except where marked)
All Rivets to be ⅞" dia and Soft Steel All bolts soft steel
All Rivetholes to be punched 11/16" and reamed to 15/16" dia
All Shop riveted Stiffeners to have a driving fit between flange angles
In size of angles, first figure indicates leg of angle shown
Webplates to be spliced so as to produce a camber of 1 inch at center of Span
Cross Ties to be framed so as to leave a camber of ½ inch in finished unloaded Span

Span calculated for 2-146 ton Engines preceded and followed by 4000 lbs per foot

Main Girders

End Shear R L + 8% Impact	154980 lbs
" " D L	55270 "
Total =	210250 lbs
Max Mom from R L + 8% Impact	3369600 ft lbs
" " " D L	1381250 " "
Effective Depth 8 33 feet	

Floor Beams

Total End Shear	59800 lbs
Max Mom from R L + 21% Impact	168190 ft lbs.
" " " D L	13500 " "

Stringers

Total End Shear	46100 lbs
Max Mom from R L + 23% Impact	76900 ft lbs
" " " D L	4000 " "

Allowable Unit Stress R L	10500 lbs per sq inch
" " D L	18000 " " " "

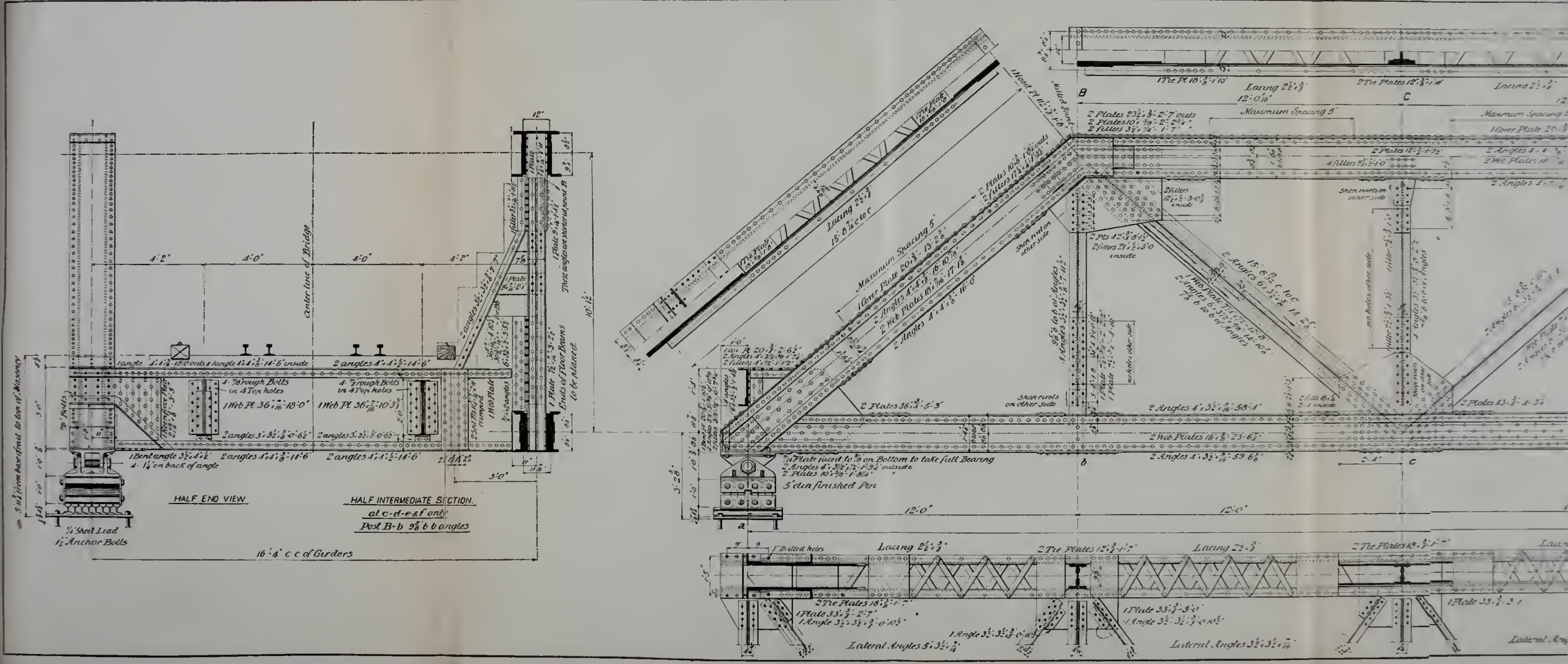
N.P.R'Y.
STANDARD PLAN.
DETAILS OF 100 FT. THROUGH PLATE GIRDER.
AND
DIAGRAMS OF TYPES.
SCALE OF DETAILS ¾" = 1'

Revised Aug 1900.

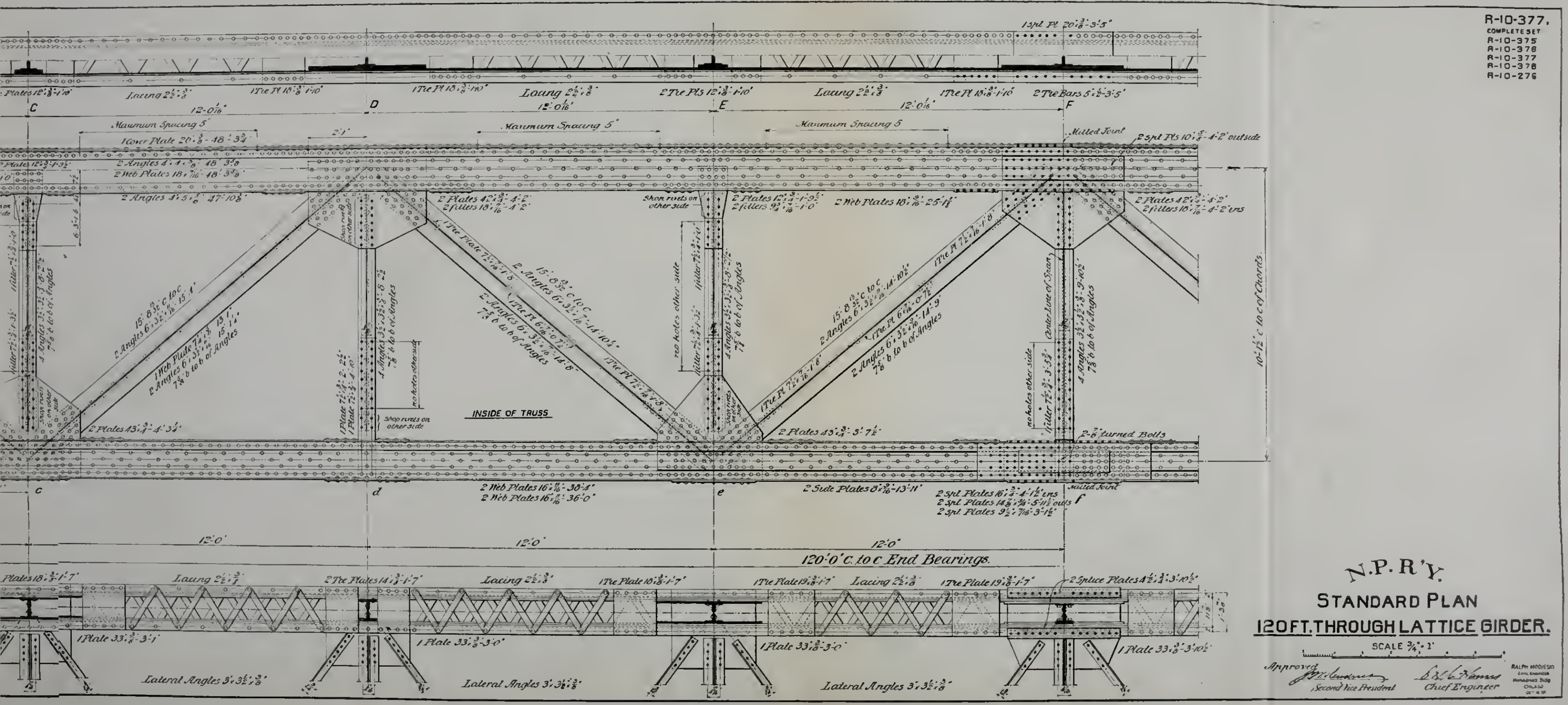
Approved J. W. Kendrick
Second Vice President

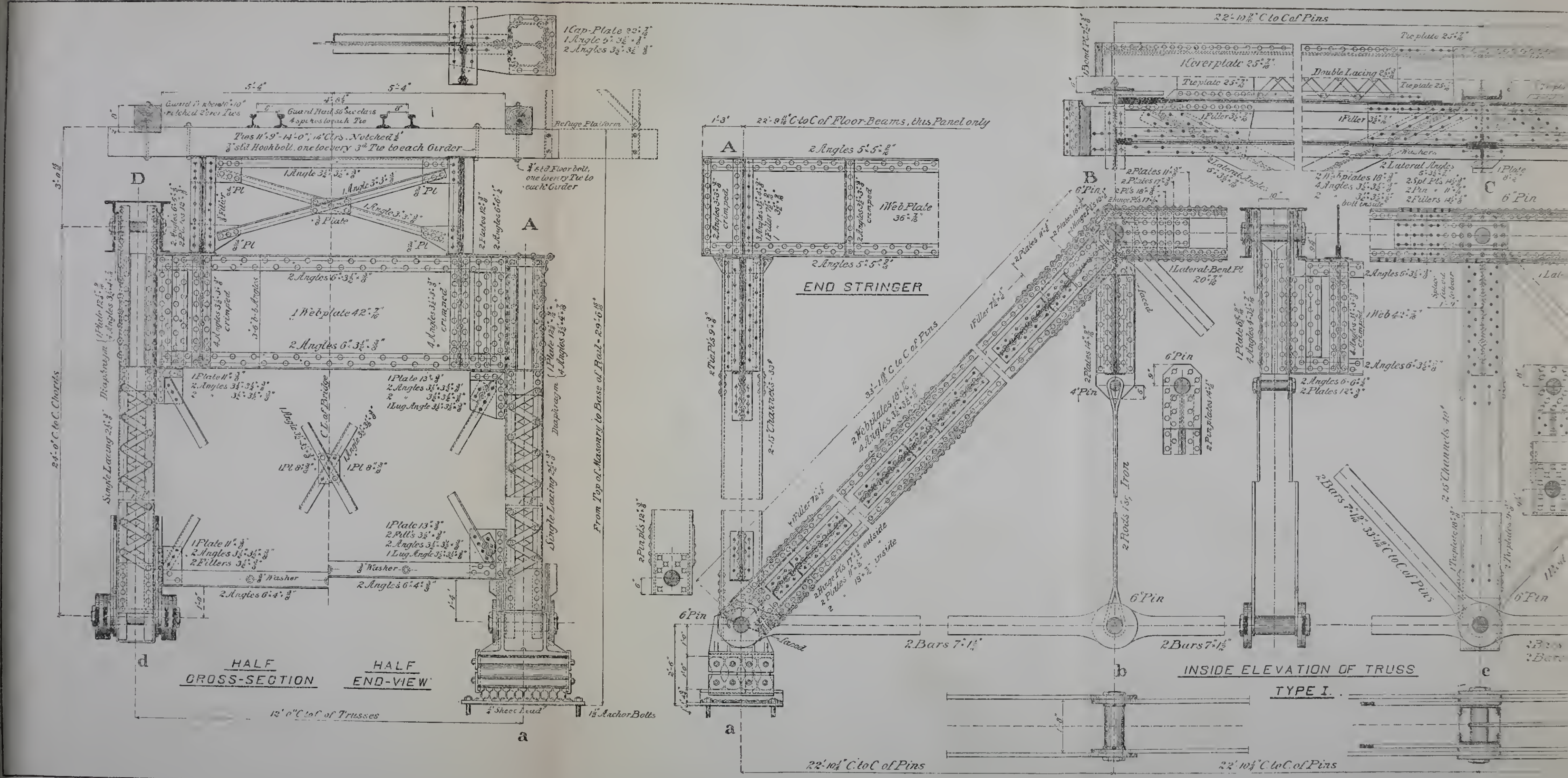
Chief Engineer

RALPH MODJESKI CIVIL ENGINEER Monadnock Bldg CHICAGO MAR 20 93

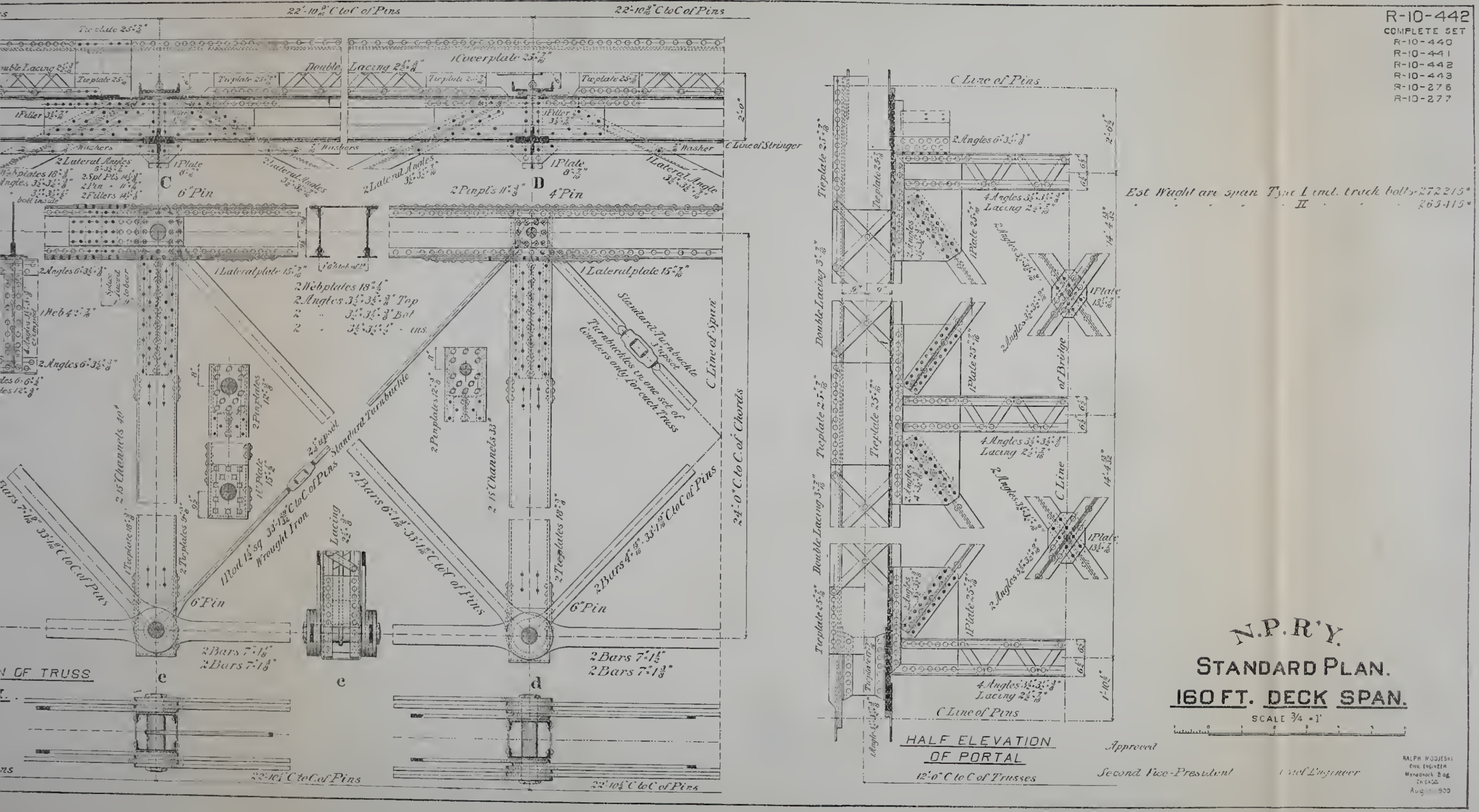

HALF END VIEW
HALF INTERMEDIATE SECTION.
at c-d-e-&-f only
Post B-b 9⅝" b b angles
16'-4" c c of Girders
4'-2"
4'-0"
4'-0"
4'-2"
12"
Center line of Bridge
1 angle 4"×4"×⅜"-18'-0" outs & 1 angle 4"×4"×⅜"-14'-6" inside
2 angles 4"×4"×½"-14'-6"
4-⅞" rough Bolts in 4 Top holes
1 Web Pl 36"×7/16"-18'-0"
1 Web Pl 36"×7/16"-10'-3¾"
2 angles 3"×3½"×⅜"-0'-6½"
1 Bent angle 3½"×4"×½"
4-1¼" on back of angle
2 angles 4"×4"×⅜"-14'-6"
2 angles 4"×4"×½"-14'-6"
¼" Sheet Lead
1½" Anchor Bolts
Ends of Floor Beams to be planed.
These angles are shortened at point B
3'-0"
10'-1½"
1'-0"
5'-11⅜" from base of rail to top of Masonry
1 Cover Pl 20"×⅜"-2'-6½"
2 Angles 4"×3½"×⅜"-1'-7½"
2 fillers 4"×½"-1'-1½"
2 Plates 36"×⅜"-5'-3"
⁷/₁₆ Plate faced to ⅜" on Bottom to take full Bearing
2 Angles 4"×3½"×½"-1'-9¼" outside
2 Plates 10"×⅜"-1'-8¼"
5" dia finished Pin
a
b
c
B
C
12'-0"
12'-0"
12'-0¼"
Lacing 2½"×⅜"
15'-8⅞" c to c
Maximum Spacing 5"
1 Cover Plate 20"×⅜"-13'-2⅞"
2 Angles 4"×4"×⅜"-16'-10⅞"
2 Web Plates 18"×7/16"-17'-1⅜"
2 Angles 4"×4"×⅜"-16'-0"
2 Plates 10"×⅜"-1'-6" outs
2 fillers 17⅝"×⅜"-1'-3⅜"
1 Hood Pl 12"×⅜"-1'-0"
Milled Joint
2 Plates 23½"×⅜"-2'-7" outs
2 Plates 10"×⅜"-2'-2⅝"
2 fillers 3½"×¼"-1'-7"
2 Pls 42"×⅜"-5'-½"
2 fillers 21"×½"-3'-0" inside
2 fillers 12½"×⅜"-3'-0⅞" inside
Shop rivets on other side
9⅜" b to b of Angles
4 Angles 3½"×3½"×⅜"-7'-11⅜"
2 Angles 6"×3½"×⅜"
1 Web Plate
7⅞" b to b of Angles
2 Angles 4"×3½"×7/16"-58'-4"
2 Web Plates 16"×⅜"-23'-6⅞"
2 Angles 4"×3½"×7/16"-59'-6⅞"
2 Plates 12"×⅜"-4'-3"
no holes other side
filler 7"×⅜"
4 Angles
1 Cover Plate 20"
2 Web Plates 18"
2 Angles 4"
Maximum Spacing
1 Tie Pl 18"×⅜"-1'-10"
2 Tie Plates 12"×⅜"-1'-10"
Lacing 2½"×⅜"
1" Drilled holes
2 Tie Plates 12"×⅜"-1'-7"
2 Tie Plates 18"×⅜"-1'-7"
2 Tie Plates 18"×⅜"-1'
1 Plate 33"×⅜"-2'-7"
1 Angle 3½"×3½"×⅜"-0'-10½"
1 Plate 33"×⅜"-3'-0"
1 Angle 3½"×3½"×⅜"-0'-10½"
1 Plate 33"×⅜"-3'
Lateral Angles 5"×3½"×7/16"
Lateral Angles 3½"×3½"×7/16"
Lateral Ang

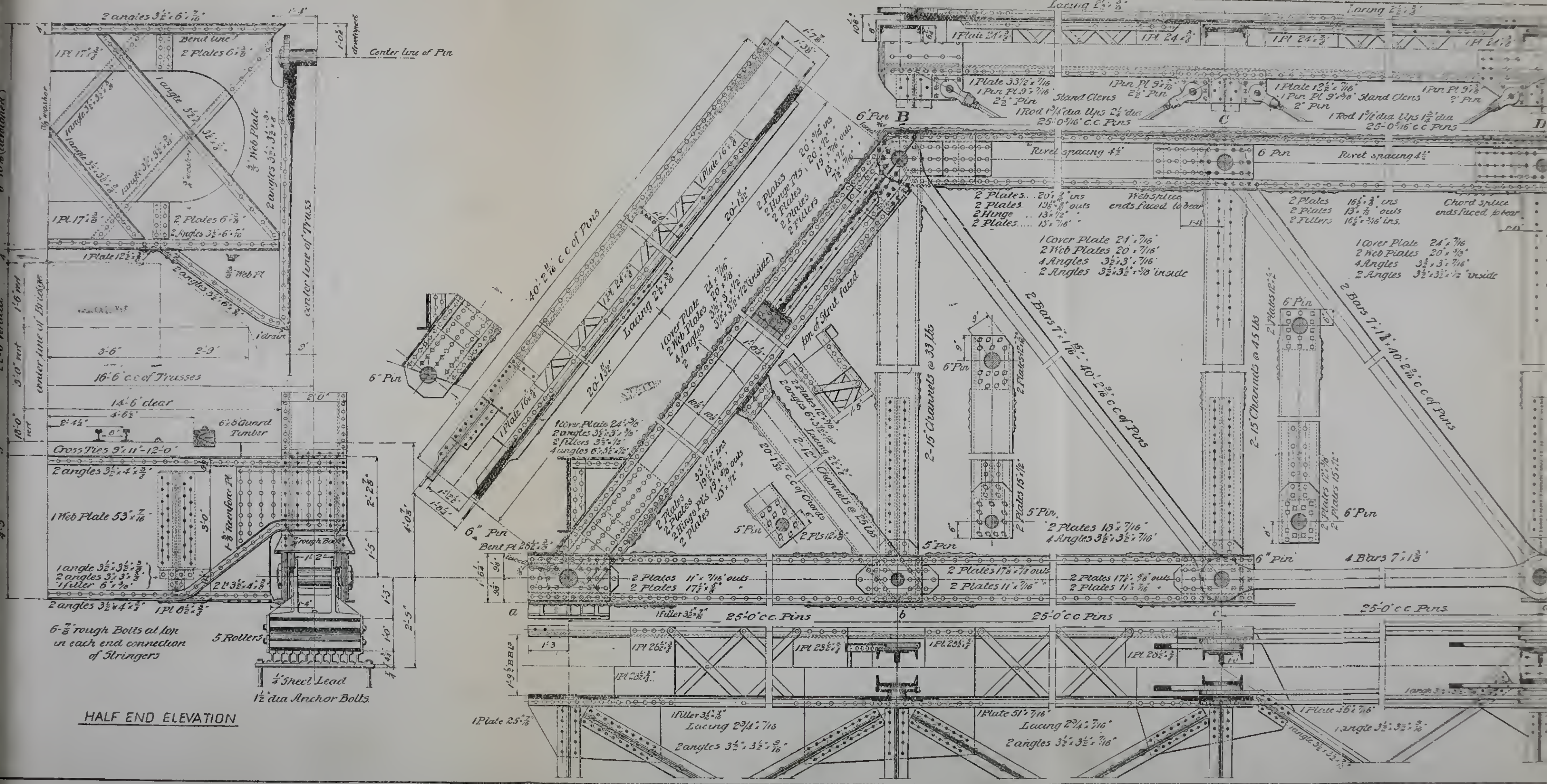
Western Society of Engineers.
Vol. VI, No. 1.—Fig. 6.
Modjeski—Northern Pacific Standard Bridge Plans.


R-10-377.
COMPLETE SET
R-10-375
R-10-376
R-10-377
R-10-378
R-10-276
1 Spl Pl 20 x ⅜ - 3'-5"
Plates 12 x ⅜ - 1'-10"
Lacing 2½ x ⅜
1 Tie Pl 18 x ⅜ - 1'-10"
1 Tie Pl 18 x ⅜ - 1'-10"
Lacing 2½ x ⅜
2 Tie Pls 12 x ⅜ - 1'-10"
Lacing 2½ x ⅜
1 Tie Pl 18 x ⅜ - 1'-10"
2 Tie Bars 5 x ½ - 3'-5"
C
12'-0 1/16"
D
12'-0 1/16"
E
12'-0 1/16"
F
Maximum Spacing 5"
2'-1"
Maximum Spacing 5"
Maximum Spacing 5
Milled Joint
1 Cover Plate 20 x ⅜ - 18'-3¾"
2 Spl Pls 10 x ⅝ - 4'-2" outside
Plates 12 x ⅜ - 1'-9½"
2 Angles 4 x 4 x ⅝ - 18'-3⅞"
2 Web Plates 18 x 7/16 - 18'-3⅞"
2 Angles 4 x 5 x ⅝ - 47'-10⅞"
2 Plates 42 x ¾ - 4'-2"
2 fillers 18 x 7/16 - 4'-2"
Shop rivets on other side
2 Plates 12 x ¾ - 1'-9½"
2 fillers 9¾ x 7/16 - 1'-0"
2 Web Plates 18 x 9/16 - 25'-1⅛"
2 Plates 42 x ¾ - 4'-2"
2 fillers 18 x 7/16 - 4'-2" ctrs
1 Tie Plate 7½ x 7/16 - 1'-8"
15'-8 13/32" c to c
2 Angles 6 x 3½ x 7/16 - 14'-10½"
2 Angles 6 x 3½ x 7/16 - 14'-8"
1 Tie Pl 6 x 7/16 - 0'-7½"
7⅝" b to b of Angles
1 Tie Pl 7½ x 7/16 - 1'-8"
15'-8 13/32" c to c
2 Angles 6 x 3½ x 7/16 - 15'-1"
1 Web Plate 7½ x 7/16 - 13'-1"
2 Angles 6 x 3½ x 7/16 - 15'-1"
7⅝" b to b of Angles
4 Angles 3½ x 3½ x ⅜ - 8'-2½"
7⅝" b to b of Angles
Filler 7½ x ⅜ - 1'-0"
no holes other side
1 Plate 7½ x ⅜ - 2'-2½"
1 Plate 7½ x ⅜ - 4'-10"
Shop rivets on other side
INSIDE OF TRUSS
2 Plates 43 x ¾ - 4'-3¼"
2 Plates 43 x ¾ - 3'-7½"
15'-8 13/32" c to c
2 Angles 6 x 3½ x 9/16 - 14'-10½"
1 Tie Pl 6 x 7/16 - 0'-7½"
2 Angles 6 x 3½ x 7/16 - 14'-9"
7⅝" b to b of Angles
1 Tie Pl 7½ x 7/16 - 1'-8"
Center Line of Span
4 Angles 3½ x 3½ x ⅜ - 9'-10½"
7⅝" b to b of Angles
Filler 7½ x ⅜ - 3'-3⅝"
no holes other side
10'-1½" c to c of Chords.
2-⅞" turned Bolts
c
d
e
f
2 Web Plates 16 x 11/16 - 30'-4"
2 Web Plates 16 x 11/16 - 36'-0"
2 Side Plates 8 x 9/16 - 13'-11"
2 Spl Plates 16 x ¾ - 4'-1½" ctrs
2 Spl Plates 14⅞ x ¾ - 5'-11½" outs
2 Spl Plates 9½ x 7/16 - 3'-1½"
Milled Joint
12'-0"
12'-0"
12'-0"
120'-0" c. to c. End Bearings.
Plates 18 x ⅜ - 1'-7"
Lacing 2½ x ⅜
2 Tie Plates 14 x ⅜ - 1'-7"
Lacing 2½ x ⅜
1 Tie Plate 18 x ⅜ - 1'-7"
1 Tie Plate 19 x ⅜ - 1'-7"
Lacing 2½ x ⅜
1 Tie Plate 19 x ⅜ - 1'-7"
2 Splice Plates 4½ x ¾ - 3'-10½"
1 Plate 33 x ⅜ - 3'-1"
1 Plate 33 x ⅜ - 3'-0"
1 Plate 33 x ⅜ - 3'-0"
1 Plate 33 x ⅜ - 3'-10½"
Lateral Angles 3 x 3½ x ⅜
Lateral Angles 3 x 3½ x ⅜
Lateral Angles 3 x 3½ x ⅜
N.P. R'Y.
STANDARD PLAN
120 FT. THROUGH LATTICE GIRDER.
SCALE ¾" = 1'
Approved
Second Vice President
Chief Engineer
RALPH MODJESKI


HALF CROSS-SECTION
HALF END-VIEW
END STRINGER
INSIDE ELEVATION OF TRUSS
TYPE I.
1 Cap-Plate 22·7/16"
1 Angle 5·3½·3/8"
2 Angles 3½·3½·3/8"
5'-4"
4'-8½"
5'-4"
Guard Hail 56 lbs class
Ties 11'·9"-14'-0", 14' Ctrs. Notched ½"
Refuge Platform
3'-0⅜"
D
A
1 Angle 3½·3½·3/8"
1 Angle 3·3·3/8"
3/8 Plate
1 Webplate 42·7/16"
2 Angles 6·3½·3/8"
Diaphragm
Single Lacing 2½·3/8"
24'-6" C to C Chords
From Top of Masonry to Base of Rail - 29'-6⅛"
C.L. of Bridge
1 Pl 8·3/8"
2 Angles 6·4·3/8"
3/8 Washer
12'-0" C to C of Trusses
1½ Anchor Bolts
d
a
22'-9⅝" C to C of Floor Beams, this Panel only
2 Angles 5·5·3/8"
1 Web Plate 36·7/16"
2 Angles 5·5·3/8"
2-15 Channels-33#
33'-1⅛" C to C of Pins
2 Webplates 18·7/16"
4 Angles 3½·3½·½"
6 Pin
2 Pin Pl's 12·3/8"
2 Bars 7·1½"
2 Rods 1⅝ □ Iron
4 Pin
B
C
b
e
22'-10¾" C to C of Pins
Coverplate 25·7/16"
Tieplate 25·7/16"
Double Lacing 2½·3/8"
1 Filler 3½·3/8"
2 Lateral Angles
1 Lateral-Bent Pl. 20·7/16"
1 Web 42·7/16"
2 Angles 6·3½·3/8"
2 Bars 7·1½" 33'-1⅛" C to C of Pins
2-15 Channels 40#
22'-10¾" C to C of Pins
22'-10¾" C to C of Pins

Western Society of Engineers
Vol. VI. No. 1.—Fig. 7.
Modjeski—Northern Pacific Standard Bridge Plans.

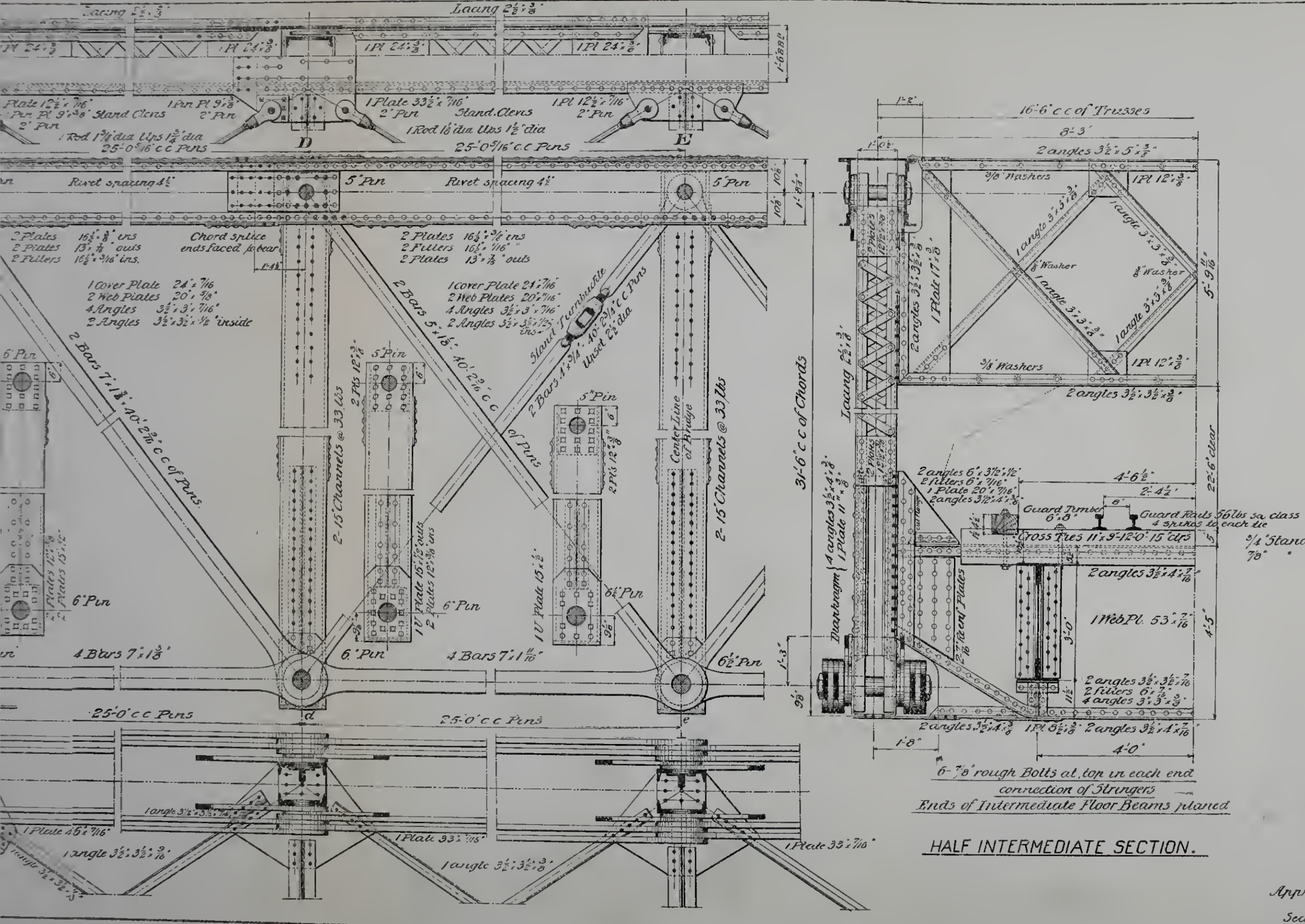




HALF END ELEVATION

WESTERN SOCIETY OF ENGINEERS
Vol VI No. 1 —FIG. 8.
Modjeski—Northern Pacific Standard Bridge Plans.

R-10-428
COMPLETE SET:
R-10-427
R-10-426
R-10-429
R-10-423
R-10-276



¾ Stand Floor bolt one to every Tie
⅞ " Hookbolt one to every 3rd Tie } to each Stringer

BILL OF TRACK MATERIAL
FOR ONE SPAN

Material	No reqd	Size	Length	Mark
Cross Ties	163	9 x 11"	12'-0"	
Guard Timber	2	6 x 8	205'-0"	
Std Floor Bolts	326	¾" dia	1'-9"	B ◻
" Hook Bolts	110	⅞" "	1'-0¾"	C ◻
◻ See Standard Drawing R-10-276				

N.P.R'Y.

STANDARD PLAN.

200FT. THROUGH SPAN.

SCALE ¾" = 1'

1 0 1 2 3 4 5 6

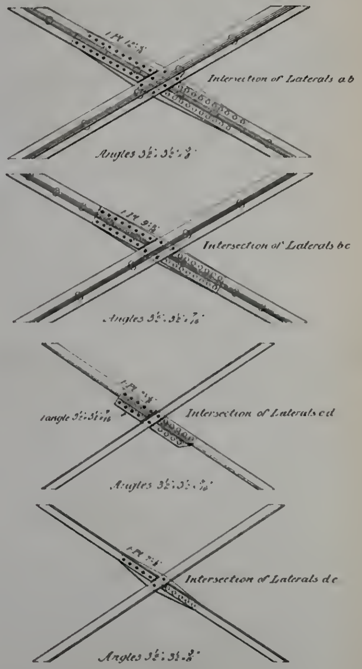
Approved

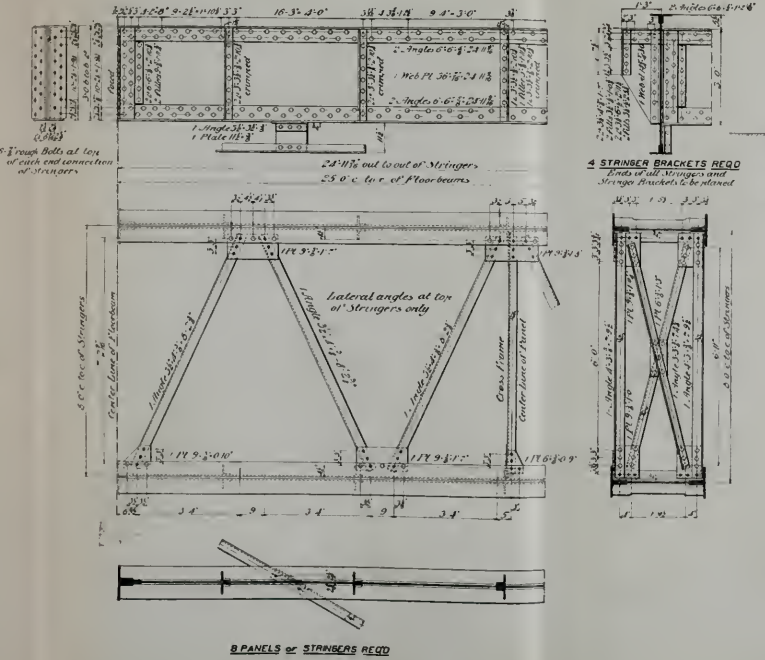
Second Vice President. Chief Engineer

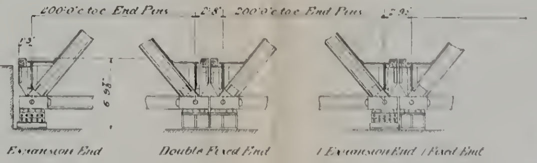
RALPH MODJESKI
CIVIL ENGINEER
Monadnock Bldg
CHICAGO
OCT 5 1899

Western Society of Engineers
Vol VI. No. 1 Fig. 9
Modjeski—Northern Pacific Standard Bridge Plans.

R-10-429
COMPLETE SET:
R-10-427
R-10-428
R-10-429
R-10-423
R-10-276







All Material to be Medium Steel (except where noted).
All Rivets to be ⅞" diam and Soft Steel
All Rivet holes to be punched 13/16" and reamed to 15/16" dia
All Stiffeners to have a driving fit between flange angles
In size of Angle, first figure indicates leg of angle shown
These notes apply to entire Span

N.P.R'Y.

STANDARD PLAN.

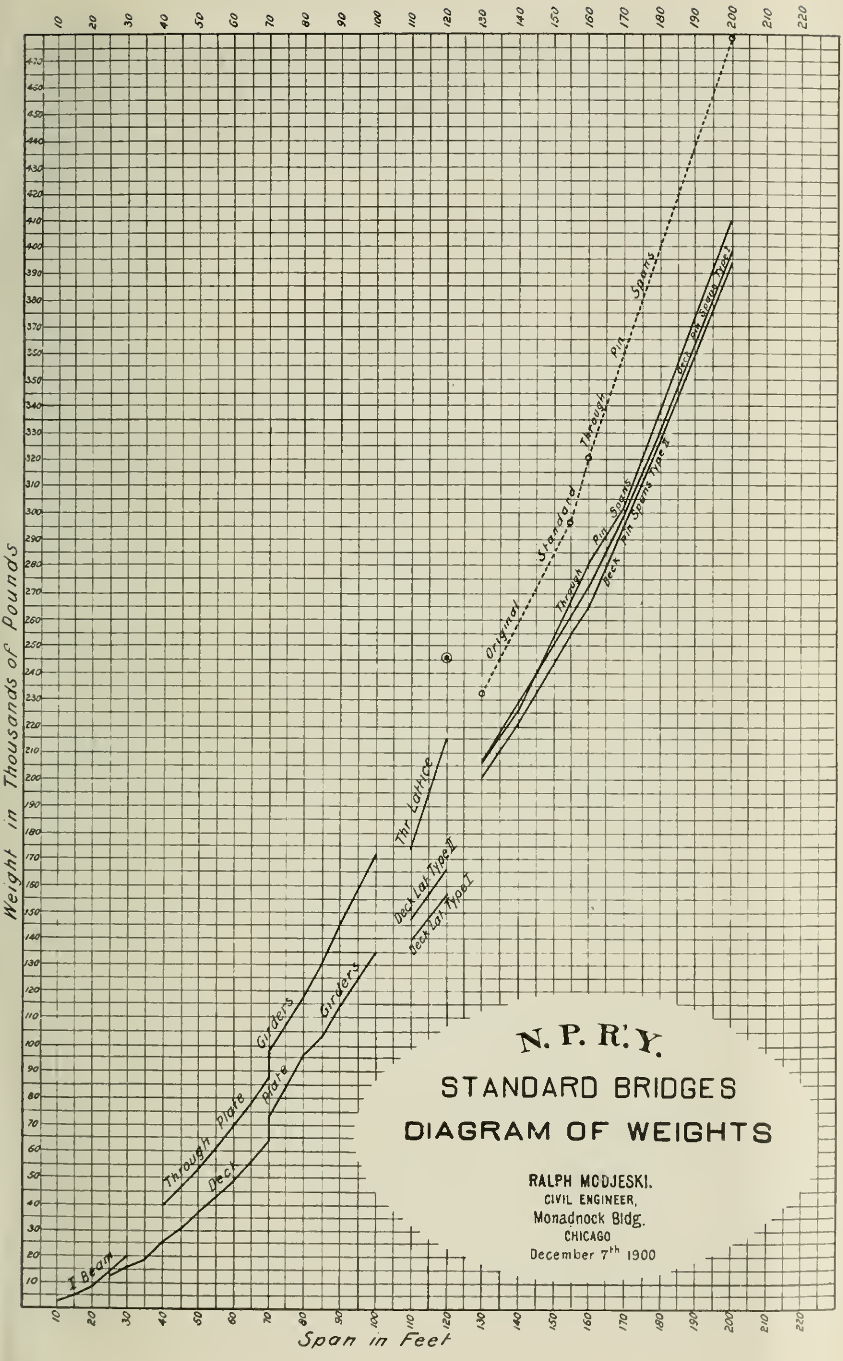
DETAILS OF 200FT. THROUGH SPAN.
AND
DIAGRAMS OF BEARINGS.

SCALE OF DETAILS ¾"-1'

Approved

General Manager Chief Engineer

RALPH MODJESKI,
CIVIL ENGINEER
Monadnock Bldg
CHICAGO
October 11th 1900



N. P. R'Y.

STANDARD BRIDGES
DIAGRAM OF WEIGHTS

RALPH MODJESKI.
CIVIL ENGINEER,
Monadnock Bldg.
CHICAGO
December 7th 1900

bridge company, weighed 479,500 pounds, while the present standard span weighs 410,000 pounds, a difference of 69,500 pounds.

The sectional material in the new standards is all medium steel reamed. The die for punching is specified 3-16 inch smaller than the nominal size of the rivet.

One of the plates shows the manner of loading girders for 100 feet through spans. One of these girders weighs 28½ tons.

DISCUSSION.

Mr. Modjeski—In my paper I have not explained what the isolated point meant which can be seen on the weight diagram on the line of 120 foot span. This is the weight of the originally designed pony riveted through span, the same one to which reference was made in the paper as having been published in the *Engineering News*, January 5, 1899. Another point which may need explanation on that same diagram, is the small difference between the weight of pin connected through and deck spans. This is due to the fact that it was desirable to make the deck span somewhat shallower than the economic depth, so as to get as much clearance above any water stream as practicable. This, and the much heavier portal bracing, contribute to make up for the saving in the weight of the floor system.

Mr. Bainbridge—I have looked over the plans and they seem to me to have been the subject of a great deal of thought and care, and I think the scheme as a whole is a very good one, for a large railroad to have plans prepared as standard. This is especially true of the western roads, as the crossings are generally of such a character that standard plans can be used in nine cases out of ten, and in the tenth case it will probably be found that no drawing is necessary on the part of the railroad company to fit the span into that location.

There are a few things about the plans that I have to criticise. One is that in the very long plate girder spans the heaviest angle used is 6 by 6 by ¾ angle. Now, there is an 8 by 8 angle that I think is very much better where so heavy sections are needed. It need scarcely be mentioned that as large percentage of the section as is practicable should be in the flange angle. Also, I want to criticise the rivets in the horizontal surface of the top flange of the girders. The life of a bridge designed for such loading as this should be 30 to 40 years, and in that time there will be eight or ten floors put on the bridge, and every time a tie is replaced a rail will have to be taken up, but the slight extra cost of making a flat flange there, without rivets to interfere with the ties would have been well repaid.

The end floor beam on the through spans seems to be badly cut up at the end. I think a little better design could be made than that, by increasing the length of the stringer there and resting the floor beam on the shoe, which is the usual practice. I think all the deck spans ought to have vertical end posts. The bottom bracing on the spans as designed is omitted, and might as well be omitted, because there is no efficient place to attach it. But if you put in vertical posts at all panel points, the bottom bracing can be attached to them, and that arrangement will make a much stiffer span. Also, about the same deck span, I think the width, 12 feet, is a little narrow for a span of that height.

Mr. Reichmann—About the only criticism I have to make on these plans is such as has been made by Mr. Bainbridge. As to the rivets in the top flanges of the girder spans, I think at present most of the western roads are using some form of top chord sections for their deck plate girder spans, with a smooth top, usually made up of angles. I think the roller bearings are rather expensive for spans of such small lengths. The C., M. & St. P. R. R. Co. does not use rollers for spans under 90 feet long.

Mr. Lee—I have no special remarks to offer as I have not been able to give this series of drawings any particular attention. I would be very glad to learn from any of the members, who have had an opportunity of discussing the facts, as to whether it is a good practice or not to introduce rollers under these spans, as has just been called attention to by Mr. Reichmann. That same question has occurred to me, and I have not had an opportunity to look into it thoroughly, but I think it is worthy of attention. I have known of one or two cases of spans that were much less than 90 feet, where the ordinary side plate seemed to be very efficient, and I would like to hear from others, who have had an opportunity of knowing the facts that bear on that subject, as to that point.

The Chairman—Now, we would like to hear from the manufacturer's standpoint. Can Mr. Horton give us some facts on that?

Mr. Horton—Some weeks ago we had a paper here outlining the exact load all railroad bridges should be built to. Mr. Modjeski's paper speaks of the fact that this is the second set of standard plans made for the Northern Pacific Railway. I believe that two sets of standard plans have been made within six years. It happens that loads are increasing so rapidly at this time that these designs of the Northern Pacific Railway are exceeded in demands by many of the Chicago roads, by as much as 33 1/3 per cent today. Speaking of this more from the facts I suggested on a previous occasion, it was idle to suggest the exact dimensions that a structure should be built for any time in the future.

As to the plans, they surely show very careful and conscientious work. I would not attempt to criticise them in any sense. However, with the refinement of mechanical execution, also in connection with the segmental roller bearings, think it a proper subject for consideration. On an 80 foot span, as compared with any practice we all have been familiar with, I am justified in stating that the machine work connected with the developing of segmental rollers, bolsters and wall plates is fully as much as the manufacture of the girder itself. This may seem excessive, but I am justified in the statement. All this comes in connection with the general question as to how much is good engineering policy to put into the cost of manufacture. It is my impression, bridge work designed and built to Cooper's specification is used more than all others throughout the country. Now, let 100 tons be a unit of cost for such work; if reaming is done for such parts as take gravity loads, it is reasonable to expect that 95 tons will represent the same cost; again, if all holes are reamed, 90 tons will be the amount of material available. My experience justifies me in saying that with the use of segmental rollers and bearings as outlined for the Northern Pacific work, 80 tons will represent the material available. This undoubtedly, is the real test of any design as to its usefulness. If the structures have been designed for simpler construction, 25 per cent greater loading might be specified, that is a 182½ ton locomotive. With reference to our observation of why bridges are removed, and we know that they are removed at intervals of about 15 years, the investigation I think turns entirely on the question of whether there is material enough in the structure, and not whether the holes were reamed. I never heard of a structure being removed because of want of reaming, neither have I ever heard of a structure being removed on account of faulty rollers.

I believe I am well within bounds in stating that structures contracted to Cooper's specifications might be built for a 182½ ton locomotive, and 5,000 pounds load following, for the same cost as a 146 ton locomotive and 4,000 pounds load following, with all the mechanical refinements. However, this is a question engineers should bear well in mind.

There is another thought that occurs to me as to the designs before us—a universal tendency to specify steel castings and wrought work for bolsters, shoes, rollers and wall plates. Those parts place no load on the structure. Cast iron about the masonry, also under the end of the bank and such places, in service 25 years, is not particularly injured, it never is pitted, never is scabbed. I doubt if any of us have ever seen wrought iron, wrought steel or steel castings that have been five years in service, taken out without being pitted and scabbed entirely out of all condition as a roller, bed plate or bolster. Steel castings cost twice as much as cast iron; in other words, you may use twice as much of cast iron for the same cost. Cast iron will make bolsters, bed plates or rollers, either round or segmental, to great advantage over any other material available. Progress was made backward when wrought material was introduced for these parts. And I believe gentlemen who have had observation will agree with me.

Mr. Pratt—I have not examined these plans at all. I am very much interested in the subject, but I am not prepared to make any comments upon the designs.

The Chairman—I will say, before the close of the discussion, that while Mr. Horton claims that a bridge has never been renewed on account of the rollers giving trouble, it is a fact that we have been compelled to put more or less expense on bridges, by jacking them up and straightening up the rollers. It is, of course, never of such consequence as to condemn the bridge or to take it down on that account, but nevertheless it required expense to adjust the rollers.

I believe, up to date, there has not been a satisfactory expansion joint designed. As to the expansion joint that Mr. Modjeski used in his design for the Northern Pacific road, I think they are expensive, requiring a lot of work. In fact, I understand they polish the surface. Do you do so, Mr. Modjeski?

Mr. Modjeski—Yes, sir. They are planed with a finishing cut, and a very smooth surface is obtained, next to polishing.

The Chairman—I agree with some of the remarks made in the criticism of the paper. One by Mr. Bainbridge, as to the width of 150 feet span, also the form of the top flange. I believe it is advisable to avoid the use of plates and rivets, and I believe that the majority of the western roads have avoided them by one method or another.

I also think that Mr. Modjeski has introduced more than is necessary in the way of field riveting in his girder at the end. I believe that if the main stiffeners were alternated it would not be necessary to rivet up the entire length of the end stiffeners. Also, in his pin connected span; the lateral connections are shown under the bottom chord bars. The only way that I see that these rivets could be driven would be by power or by striking them from underneath by hand, which is worse than no riveting at all. By what method did you intend those should be driven, Mr. Modjeski?

Mr. Modjeski—I presume, the best way the riveter can get at it. If they had air, they would use air; but on the western roads it is very seldom possible to get compressed air for spans so far apart. But they seem to be able to drive the rivets.

The Chairman—Isn't it true, they can't drive them by hand, except by striking up from underneath?

Mr. Modjeski—These rivets are usually driven before all the chord bars are fitted up. I have no reports of any difficulty whatever from the erectors.

WRITTEN DISCUSSION.

Geo. S. Morison—The Northern Pacific Standard Bridge Plans represent a set of plans carefully worked out by an engineer. While to Mr. Modjeski is due the credit of the work, my connection with these designs has been such that I must be held responsible for some of the special features which have been criticised in this discussion. In recommending these special features I considered that the superstructure of a bridge is an entirely useless thing itself; the bridge is only complete when superstructure and the substructure are combined. Furthermore, such a bridge in itself is useless, it has value only as part of a railroad.

There are undoubtedly changes which could be made in the interest of economy in the superstructure. It is cheaper, as Mr. Bainbridge proposes, to rest the end stringers on masonry or on a shoe and to save the expense of an end floor beam which involves some complicated details. It will save metal to use small rollers and shallow shoes, reducing the amount of metal below the end pins to a minimum. It does not follow, however, that these changes will reduce the cost of the whole structure; they will require more masonry and in many places the masonry will cost more than the metal which is saved.

It has been my practice for many years to keep the superstructure well above the masonry. Except in some rare instances where special considerations governed, I have seldom made the distance from masonry to base of rail less than 6.5 feet and in one case I have made it 13 feet. This has involved much metal which might have been saved, but it has saved a great deal of masonry, it has given an opportunity to distribute the weight satisfactorily over the masonry, thus reducing the safe size of the whole pier, and it has made a structure which is everywhere easily accessible for inspection and care.

As Mr. Horton has said, bridges are not condemned because they are not reamed and they are not condemned because their expansion bearings are defective. It is equally true that they are not condemned because the quality of metal is inferior; quality of metal and reaming are both things which cannot be determined after the bridge is built, but the same course of reasoning which is used to recommend the omission of reaming can be used in favor of the cheapest class of metal and the entire elimination of both mill and shop inspection. There are few engineers who would be willing to accept this logical result. The permissible strains which can be allowed in a bridge are dependent on quality of material and character of workmanship. There is something else to be considered than the ground on which a structure would be condemned. We are looking to the safety of the bridge during its life, not to the time when it must be renewed. Furthermore if intelligence increases at the same rate during the next twenty-five years that we have seen it increase during the past, records of quality of material and quality of workmanship will have an influence when the time comes to condemn the bridges we are building now.

There is no part of a bridge which is generally more defective than its bearing on the masonry, whether at the fixed end or at the expansion end. This has little influence on the superstructure and like Mr. Horton I have never heard of a bridge being removed on account of faulty rollers. On the other hand, I think every engineer who has had much railroad or bridge experience, has known many bridges in which the masonry has been injured by faulty rollers and by defective bearings. The injury is not to the superstructure but to the piers which carry that superstructure; they have to take the thrusts and bear the vibrations which they are not designed to resist. The principal defects of expansion bearings are two. First, the rollers are too small and the bearing plates too thin so that the rollers become bedded in valleys from which they can never climb. Second, the rollers become clogged with dirt and can only move by crushing this out of the way. Usually there is a combination of the two. There is no possible way of keeping dirt from getting in among the rollers; I once tried packing them with end plates and rubber gaskets but it was an absolute failure. The only way is to provide a device from which the dirt will blow out as easily as it will get in; the rail plate bearing fills this requirement and it is the only device that I have ever seen that does. Segmental rollers are undoubtedly expensive, especially so if made of forged steel, but they are 12 inches high and as compared with the usual three inch rollers they represent a saving of 9 inches of masonry, which extends over the whole size of the bridge seat. Furthermore, I doubt the necessity of making these rollers of steel and in a bridge which I am now building I am using cast iron rollers with no other machine work than that of the rolling surface and the bolts. These rollers move; they are sensitive to slight changes in length of superstructure; they relieve the masonry from any appreciable thrust and they relieve the superstructure from the irregular strains which necessarily belong to that thrust.

With reference to the form of end floor beam and the connections of this floor beam with the posts, a through bridge of the ordinary design is a pretty loose structure; the end posts which must carry all wind pressure down to the masonry are stiffened only at the top, the bottom laterals bring a thrust on the bolsters which tend to skew them. This particular floor beam attachment was designed to overcome these difficulties; it is a detail which stiffens the end posts at the bottom as well as the top, which makes a good connection with the bottom lateral system, and which furthermore, makes the entire span a complete unit consisting of four planes each braced in itself, each rigidly connected with the two adjoining planes, and the whole supported on four terminal points where the trusses connect with the lateral system of the bottom plane. No blow from a passing train is received on the masonry, except through the elastic truss. The firm connections at the foot of the end posts combined with the stiff bottom chord in the end panels, make a structure which cannot be pulled to pieces if struck by a derailed train; it cannot affect the masonry except as a whole; it is the most rigid design for a pin-connected structure that I know; distortions are limited to changes of shape produced by strain which are all right, and are not due to changes of shape caused by lost motion which are all wrong.

CONCLUSION.

Mr. Modjeski—In saying that the heaviest angles used in the flanges of plate girders are 6 x 6 x ¾ inches, Mr. Bainbridge must have overlooked the 100 foot through plate girder, where a 6 x 8 x ¾ inch angle is shown. On account of the extra cost of about $2.00 per ton and the difficulty of obtaining them in small orders, the 8 inch angles present no advantage over the 6 inch, and, in the writer's opinion, as long as the 6 x 6 inch angles are sufficient for properly transmitting the strains from the web to the flanges, they are all that is necessary. In fact, it is objectionable to put too much material into the flange angles as tending to reduce the effective depth of the girder, and therefore requiring more metal.

As to Mr. Bainbridge's second criticism, with regard to rivets in flanges of deck girders, the matter has received the writer's careful attention at the time the designs were decided upon. It must be said that the renewals of floors on the Northern Pacific Railroad are not nearly as frequent as Mr. Bainbridge states. The writer acknowledges that the cost of framing the ties in the designs under consideration is somewhat more during the assumed life of the bridge of 40 years, than the saving in the cost of the steel work. A little calculation will show that if 2,000 or 3,000 pounds can be saved in the span, there will be no difference in the cost at the end of 40 years, if compound interest be taken into account. There is no question, however, that apart from the question of framing the ties, the design with cover plates is far better and more effective than any other which has ever been invented with the view of obtaining a smooth top flange. The latter are generally faulty either in the arrangement of stiffeners and splices, or in the excessive length of rivets through the side plates, or n the excessive weight of metal. Probably the most common design with smooth top flange is the one in which the flanges are built of four angles, two of them placed in the usual manner, with the horizontal leg flush with the top edge of the web, and the other two placed immediately below the former with the vertical leg turned up. The side plates are placed against the vertical legs of the flange angles. The stiffeners are butted against the lower pair ef flange angles to which the lateral system is also attached. There is a very serious objection to this design, and that is, that the top flange of the girder, which consists of four angles and side plates, is attached to the rest of the girder by the thickness of the web only; in other words, the shear due to wind and lateral vibration must be taken entirely by the web at the point where the stiffeners butt against the lower pair of flange angles. What is more, the efforts of wind and lateral vibrations are applied at the top of the flange and acting on a lever, with the stiffeners as point of support, tend to tear out the web at the root of the lower pair of angles.

In addition to what Mr. Morison says about the end floor beam design, the writer would add another objection to placing it directly on the shoe, and that is that at the roller end it centers, on a few rollers, the effect of the hammering from passing trains, while in the design that was used here this effect is distributed evenly, besides being reduced by indirect application. I do not agree with Mr. Bainbridge in his statement that the end floor beam is badly cut up. It is no more so than the intermediate beams, and it sustains a smaller load. The design used by the writer affords some additional bracing for the end posts which, especially in the case of pony through spans, is an important advantage. It also avoids special end stringers and stringer laterals.

Mr. Bainbridge mistakes the cause which led the writer to leave out the bottom lateral bracing in the deck spans. A pin connected deck span should never be put on vertical end posts. The latter should be inclined, where possible, on both ends and certainly at least on one end. The reason becomes apparent when it is considered that with vertical end posts there is no stress in the end panels of the bottom chord. Mr. Bainbridge proposes to use a bottom lateral system with vertical end posts. How does he propose to take care of the expansion? By the rocking of the end posts, or by connecting them rigidly to the bottom chord? In the first case, the end panel of the bottom chord will have no stress at all; in the second case, it will have reversals of stresses due to expansion and contraction. I fail to see how a bottom lateral system can be made effective under the circumstances. The lost motion in the end chord sections will permit of vibrations, whether there is a bottom lateral system or not. The lateral bracing should be put where it is mostly needed, namely, as near the rolling load as possible. The small wind load on the bottom chords can be very effectively transmitted to the top system by means of sway frames. The effect of vibration and wind should further be transmitted to the piers by the shortest possible way. This is done by means of inclined end posts, and rigid bracing between them. Such an arrangement is much stiffer than the one proposed by Mr. Bainbridge.

With regard to the width of the 160 foot deck span, which both Mr. Finley and Mr. Bainbridge pronounce as too narrow, the writer has given this point, as well as all other important points, a great deal of personal study. The writer's rule for wide deck spans is to make the width 12 feet center to center of trusses for single track spans up to 160 feet, and increase it by six inches for every ten feet of increase in length. This would make the width of a 200 foot span 14 feet. The writer's reason for this is that anything above what is just enough would be pure waste. That it is enough, is shown by figures demonstrating that there is no possible uplift on the windward bearings under the greatest possible overturning moment due to wind. To provide for a wind effort somewhat in excess of the maxima conditions usually calculated, the bearings are designed in such a manner as to lock the end posts to the base plates against uplifting. It is assumed, and is to be hoped for the surrounding country, that this lock will never come into play.

Mr. Finley states that he has recently built a 114 foot deck span without any expansion rollers. In the writer's opinion, this is a step backward. I have had occasion, during my examinations of old structures, to see frequently the effects of improper provision for expansion. I have seen stone piers moving to and fro under the action of expansion, while the rollers, always much too small, did not move a particle. I have also seen piers cracked in two, the crack opening and closing under the same action. In one instance, this happened under a short span where no rollers were used. As far as the steel is concerned, rollers might very often be dispensed with; but if the preservation of masonry be considered, they are indispensable, even for spans below 100 feet. As to the expense, which is mentioned by several of the gentlemen taking part in the discussion, as well as entered into more thoroughly by Mr. Horton, the writer would say that if rollers were used they should be of large diameter, and their perfect working cannot be insured without somewhat expensive details. This extra cost will be largely compensated by the reduced cost of maintenance, besides some saving in the cost of masonry, of which Mr. Morison speaks in his discussion.

Taking up Mr. Horton's discussion with regard to the advisability of preparing standard plans, the writer wishes to say that the set prepared by him is the only one that the Northern Pacific Railroad completed; the former set was incomplete. It is true, that the loads increase constantly, but the writer believes that these standard spans can safely withstand an increase of 50 per cent in loading without undue overstraining of metal, and it will take some time before such an increase in rolling stock will take place.

Mr. Horton apparently has the impression that the writer used cast steel in wall plates. Under all fixed ends of spans with expansion rollers, cast iron wall plates are used of such height as to make the top of masonry at the same elevation under both ends of span. The writer has used cast steel principally in shoes and bolsters subjected to bending, as he strongly objects to the use of cast iron for such a purpose. The shoes, except in the smaller girders, would be made of wrought steel by most designers, and not of cast iron. The writer always considered a shoe or pin-bearing bolster built up of plates and angles as a makeshift, and as costing very little less than cast steel.

Steel castings cost twice as much as cast iron at present, but they are decreasing in price constantly. In the Rock Island draw span, the writer has used them under the turntable and at expansion bearings, and they seem to be nearly as good as new, although they were put in just five years ago. On the Memphis bridge, 15 inch rollers were used. I have not heard of their being removed, although put in nine years ago. The writer thinks that in railway bridges with properly designed rollers, many more examples of success of the steel roller can be given than of its failure on account of pitting or rusting.

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CXII.

RAIL TOP CULVERTS.

Albert Reichmann, M. W. S. E.

Read January 23, 1901.

The rapid increase of late years in the weight and speed of the rolling stock has required the western railroads to make extensive improvements in their track and bridges. On their main lines the wooden bridges are rapidly being replaced by some form of more permanent construction, made either of iron or masonry, or a combination of both. For the smaller waterways, where practicable and not too expensive, some form of culvert is used, as a rule Fig. 1. This avoids a break in the track, which is very objectionable, as the bank usually heaves from the action of the frost at the abutments of a bridge, putting the track in bad surface and making it poor riding. Besides, it is desirable to have the roadbed continuous, in case of derailment. It might also be stated that when a culvert is once in place, little or no labor is required to maintain it. What is commonly known as a rail top culvert has been built quite extensively of recent years by the bridge and building department of the Chicago, Milwaukee & St. Paul Ry. Co., and it is the intention of this paper, to describe this class of culverts as built by that company.

The rail top culvert is built for spans varying from five to twelve feet in the clear. Sometimes, for larger openings, two culverts are placed adjacent to each other, with a common pier, as shown in Fig. 2. They are usually designated as double rail top culverts. The heights of these culverts range from four to twelve feet in the clear. When the span exceeds twelve feet in the clear, an "I beam" decking, usually made of old bridge material, is used instead of rails.

For smaller openings than those mentioned above, either a wooden box culvert or cast iron pipe is used, the intention being when the wooden box has outlived its usefulness to draw an iron pipe through it. These culverts have been built under banks varying from 2 feet 6 inches to over 50 feet from the top of the culvert to the base of the rail. Formerly they were mostly built with rubble masonry walls, with a concrete cover over the rails, but of late years they have been built entirely of concrete.

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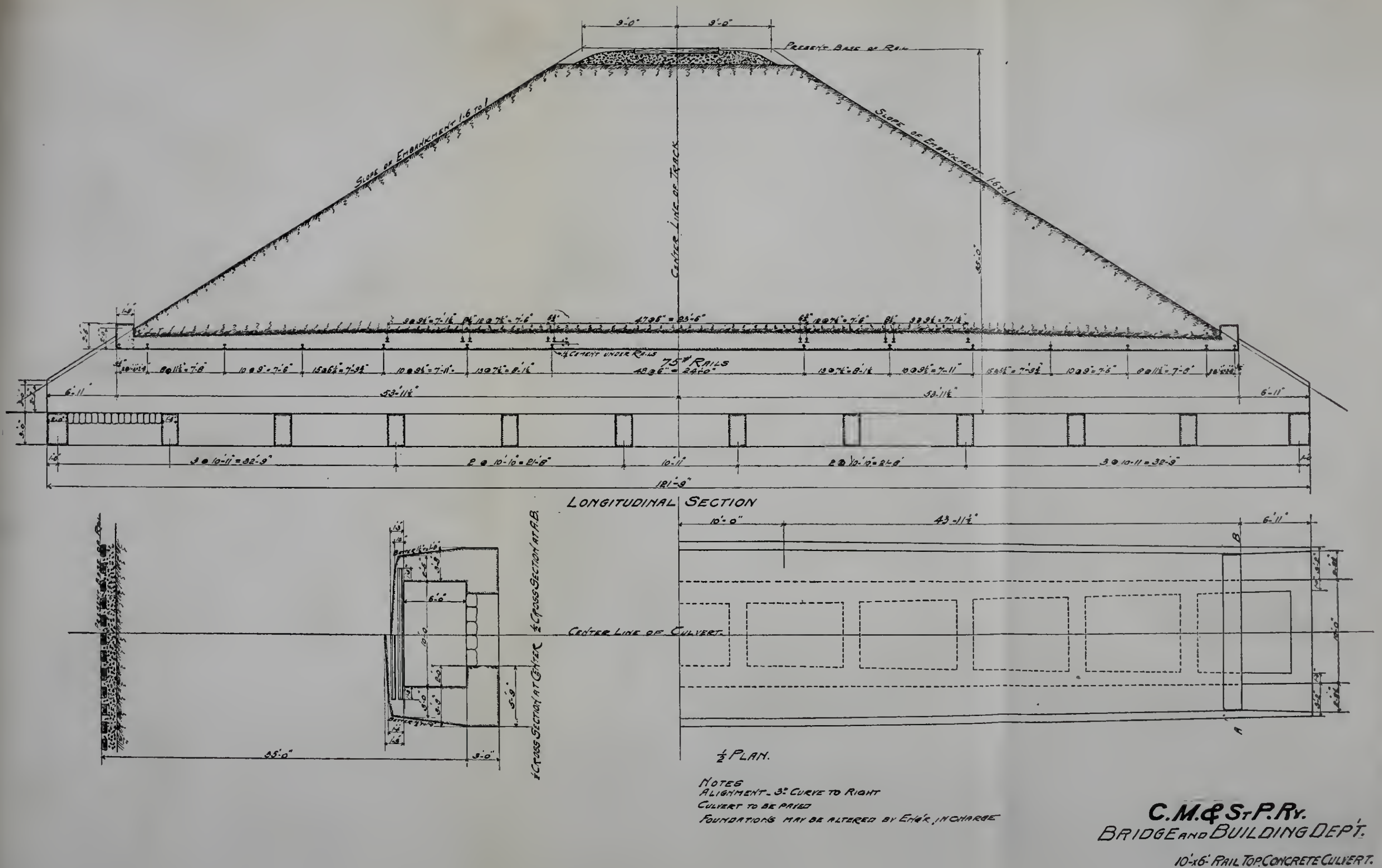
Western Society of Engineers.
Vol. VI. No. 1.—Fig. 1.
Reichmann—Rail-Top Culverts.



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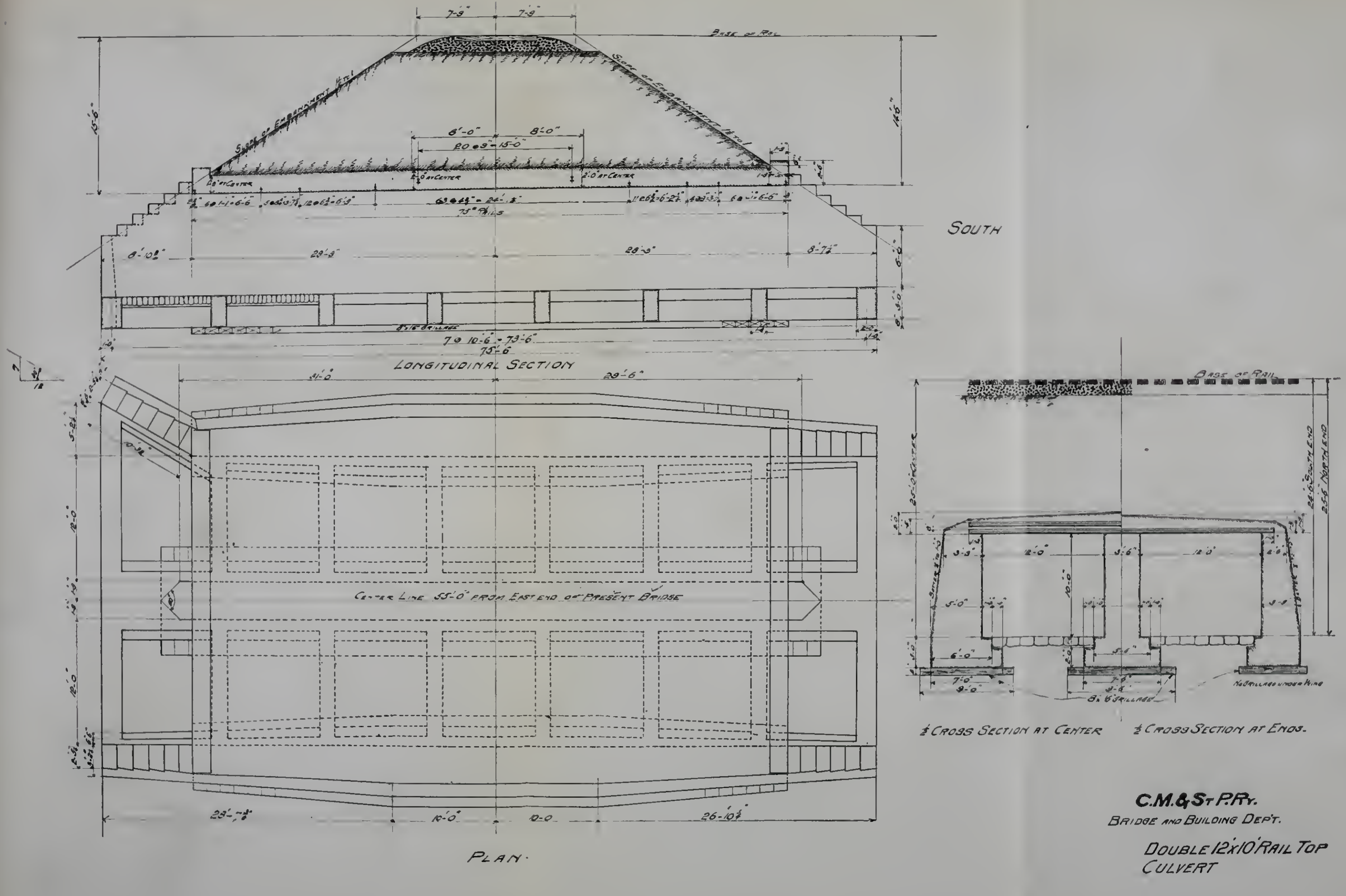
WESTERN SOCIETY OF ENGINEERS.
Vol. VI. No. 1.—FIG. 2.
Reichmann—Rail-Top Culverts.



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Western Society of Engineers.
Vol. VI. No. 1.—Fig. 3.
Reichmann—Rail-Top Culverts.

C_1=2'-6" TO 5'-0."

H.	G	R.	F.	S=6'. P_1.	S=8'. P_1.	S=10'. P_1.	S=12'. P_1.
4'	2'-3"	2'-9"	3'-9"	D=0.61 T=097	D=0.68 T=1.11	D=0.74 T=1.23	D=0.81 T=1.36
6'	2'-6"	3'-3"	4'-3"	D=0.72 T=1.07	D=0.78 T=1.19	D=0.84 T=1.30	D=0.90 T=1.42
8'	2'-6"	3'-6"	4'-6"	D=0.83 T=1.17	D=0.89 T=1.29	D=0.94 T=1.39	D=1.00 T=1.50
10'	3'-0"	4'-3"	4'-9"	D=1.06 T=1.42	D=1.11 T=1.52	D=1.16 T=1.62	D=1.21 T=1.72
12'	3'-3"	4'-9"	5'-3"	D=1.20 T=1.55	D=1.25 T=1.65	D=1.30 T=1.74	D=1.34 T=1.84

C_1=5'-0" TO 10'-0."

H.	G.	R.	F.	S=6'. P_1.	S=8'. P_1.	S=10'. P_1.	S=12'. P_1.
4'	2'-3"	2'-9"	3'-9"	D=0.99 T=1.29	D=1.13 T=1.48	D=1.26 T=1.66	D=1.40 T=1.85
6'	2'-6"	3'-3"	4'-3"	D=1.09 T=1.37	D=1.20 T=1.53	D=1.32 T=1.69	D=1.44 T=1.86
8'	2'-9"	3'-9"	4'-9"	D=1.19 T=1.46	D=1.29 T=1.60	D=1.40 T=1.75	D=1.51 T=1.91
10'	3'-3"	4'-6"	5'-0"	D=1.46 T=1.75	D=1.56 T=1.89	D=1.66 T=2.02	D=1.76 T=2.16
12.	3'-9"	5'-3"	5'-6"	D=1.63 T=1.89	D=1.72 T=2.02	D=1.81 T=2.14	D=1.90 T=2.27

C_1=10'-0" TO 15'-0."

H	G.	R.	F.	S=6'. P_1.	S=8'. P_1.	S=10' P_1.	S=12'. P_1.
4'	2'-6"	3'-0"	4'-0"	D=1.36 T=1.60	D=1.55 T=1.83	D=1.73 T=2.05	D=1.92 T=228
6'	2'-9"	3'-6"	4'-6"	D=1.44 T=1.67	D=1.61 T=1.88	D=1.78 T=208	D=1.94 T=2.28
8'	3'-0"	4'-0"	5'-0"	D=1.54 T=1.77	D=1.69 T=1.95	D=184 T=2.13	D=1.99 T=231
10'	3'-6"	4'-9"	5'-6"	D=1.71 T=1.94	D=1.85 T=2.10	D=198 T=2.27	D=2.12 T=244
12'	4'-0"	5'-6"	6'-0"	D=1.91 T=2.14	D=2.04 T=2.30	D=2.16 T=2.44	D=2.29 T=2.60

C_1=15'-0" TO 20'-0."

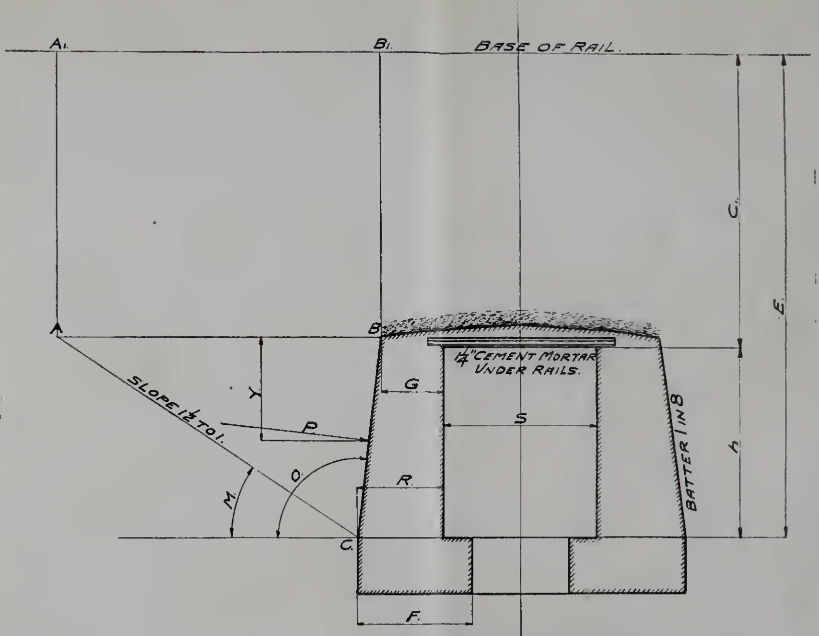
H.	G.	R.	F.	S=6'. P_1.	S=8'. P_1.	S=10'. P_1.	S=12'. P_1
4'	2'-6"	3'-0"	5'-0"	D=1.39 T=1.56	D=1.59 T=1.78	D=1.79 T=2.01	D=1.99 T=224
6'	2'-9"	3'-6"	5'-6"	D=1.48 T=1.64	D=1.66 T=1.85	D=1.84 T=2.05	D=202 T=226
8'	3'-3"	4'-3"	6'-3"	D=1.58 T=1.74	D=1.74 T=1.92	D=1.90 T=2.11	D=2.06 T=229
10'	3'-9"	5'-0"	7'-0"	D=1.69 T=185	D=1.83 T=2.01	D=1.97 T=2.17	D=2.11 T=2.33
12'	4'-3"	5'-9"	7'-6"	D=1.88 T=204	D=2.01 T=2.19	D=2.14 T=234	D=2.29 T=248

C_1=20'-0" TO 25'-0."

H	G	R	F.	S=6'. P_1.	S=8' P_1.	S=10'. P_1.	S=12'. P_1.
4'	2'-6"	3'-0"	5'-0"	D=1.69 T=1.84	D=1.94 T=2.11	D=2.19 T=2.39	D=2.44 T=2.66
6'	3'-0"	3'-9"	5'-9"	D=1.77 T=1.91	D=1.99 T=2.16	D=2.20 T=239	D=2.44 T=2.63
8'	3'-6"	4'-6"	6'-6"	D=1.87 T=201	D=2.06 T=2.22	D=2.25 T=243	D=2.44 T=2.64
10'	4'-3"	5'-6"	7'-6"	D=1.98 T=2.12	D=2.14 T=2.30	D=231 T=248	D=248 T=267
12'	4'-6"	6'-0"	8'-0"	D=2.09 T=2.23	D=2.25 T=240	D=240 T=2.57	D=2.56 T=2.74

C_1=25'-0" TO 30'-0."

H.	G.	R.	F.	S=6'. P_1.	S=8'. P_1.	S=10'. P_1.	S=12'. P_1.
4'	2'-6"	3'-0"	6'-0"	D=1.66 T=1.77	D=1.91 T=2.04	D=216 T=231	D=241 T=257
6'	3'-0"	3'-9"	6'-9"	D=1.76 T=1.87	D=1.98 T=2.10	D=220 T=234	D=242 T=258
8'	3'-9"	4'-9"	7'-9"	D=1.88 T=1.99	D=2.07 T=219	D=2.26 T=2.40	D=246 T=261
10'	4'-9"	6'-0"	9'-0"	D=2.01 T=2.12	D=2.18 T=230	D=2.35 T=2.48	D=251 T=265
12'	5'-0"	6'-6"	9'-6"	D=2.13 T=2.24	D=2.29 T=241	D=2.44 T=2.57	D=2.60 T=2.74



CROSS SECTION AT CENTER.

D=DEAD LOAD PRESSURE AND,
T=DEAD AND LIVE LOAD PRESSURE PER SQ.FT. IN TONS OF 2000 LBS.
WEIGHT OF EARTH TAKEN AS 100 LBS. PER CU.FT.
WEIGHT OF MASONRY TAKEN AS 160 LBS. PER CU.FT.
LIVE LOAD=5000 LBS. PER LIN. FT. SPREAD OVER 8'-0" AT BASE OF RAIL AND SPREADING FROM THERE AT THE RATE OF 6" TO 12" VERTICAL.
CALCULATIONS FOR EACH TABLE ARE FOR THE GREATER DEPTH.
Q=WEIGHT PER SQ. FT. OF THE LOAD ABOVE THE SURFACE A-B.
P=PRESSURE NORMAL TO WALL, PER RUNNING FT. OF WALL.
Y=DISTANCE OF RESULTANT P. FROM TOP OF MASONRY.
ANGLE M.=33°-40'.
ANGLE O=97°-08'.

$$P=\left(\tfrac{1}{2}WH^2+QH\right)\frac{\sin^2\frac{1}{2}(O-M)}{\sin O\,\sin^2(O+M)}=\left(\tfrac{1}{2}WH^2+QH\right)0.34.$$

$$Y=\frac{2WH+3Q}{3WH+6Q}H.$$

C.M.& St.P.Ry.
BRIDGE AND BUILDING DEP'T.
RAIL TOP CULVERTS.

7

y

n
s
s
t
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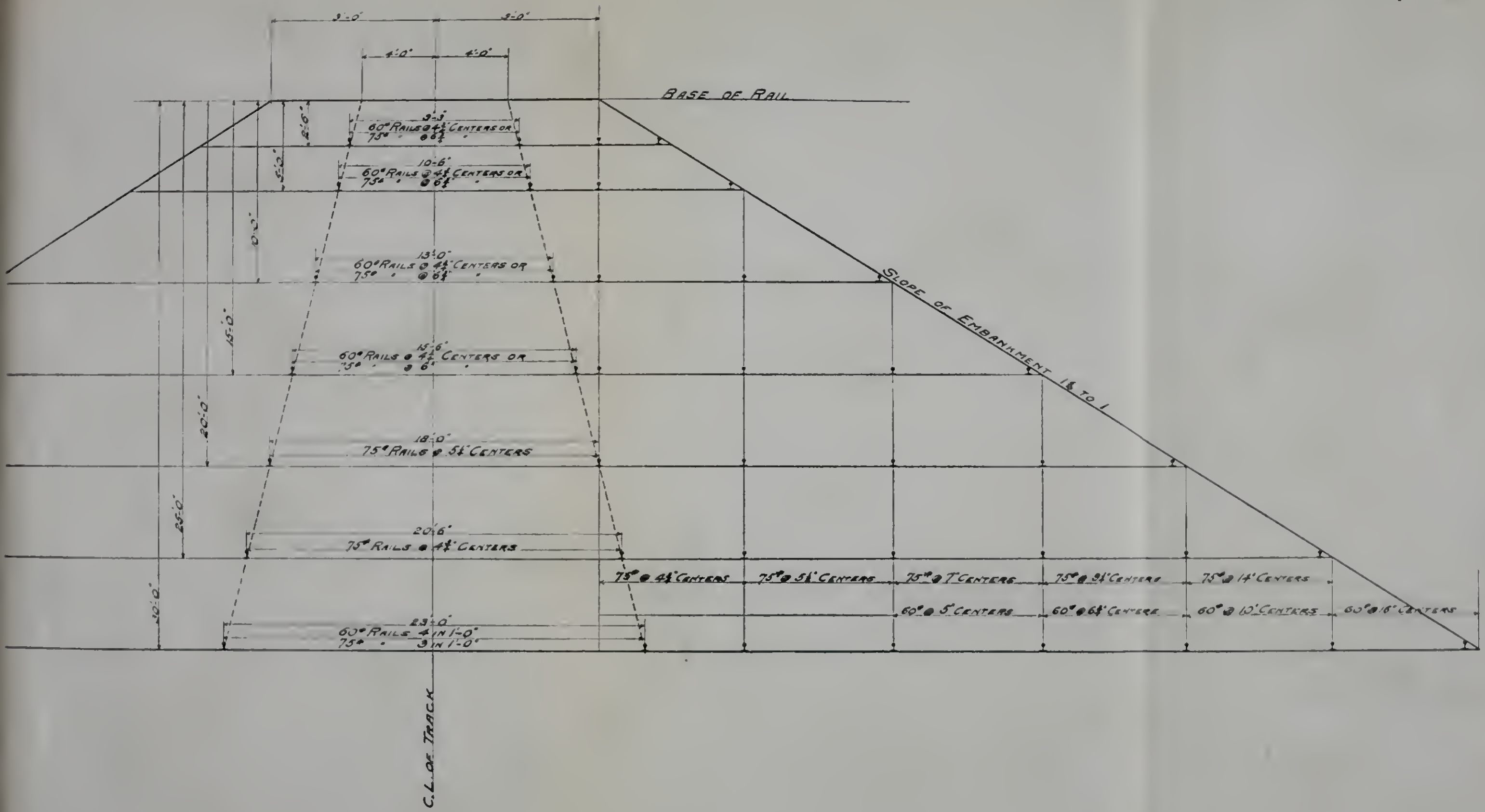
f

l

Western Society of Engineers.
Vol. VI. No. 1.—Fig. 4.
Reichmann—Rail-Top Culverts.



C.M. & St P. Ry.

BRIDGE AND BUILDING DEP'T

RAIL SPACING FOR 8 FT CULVERTS

7

y
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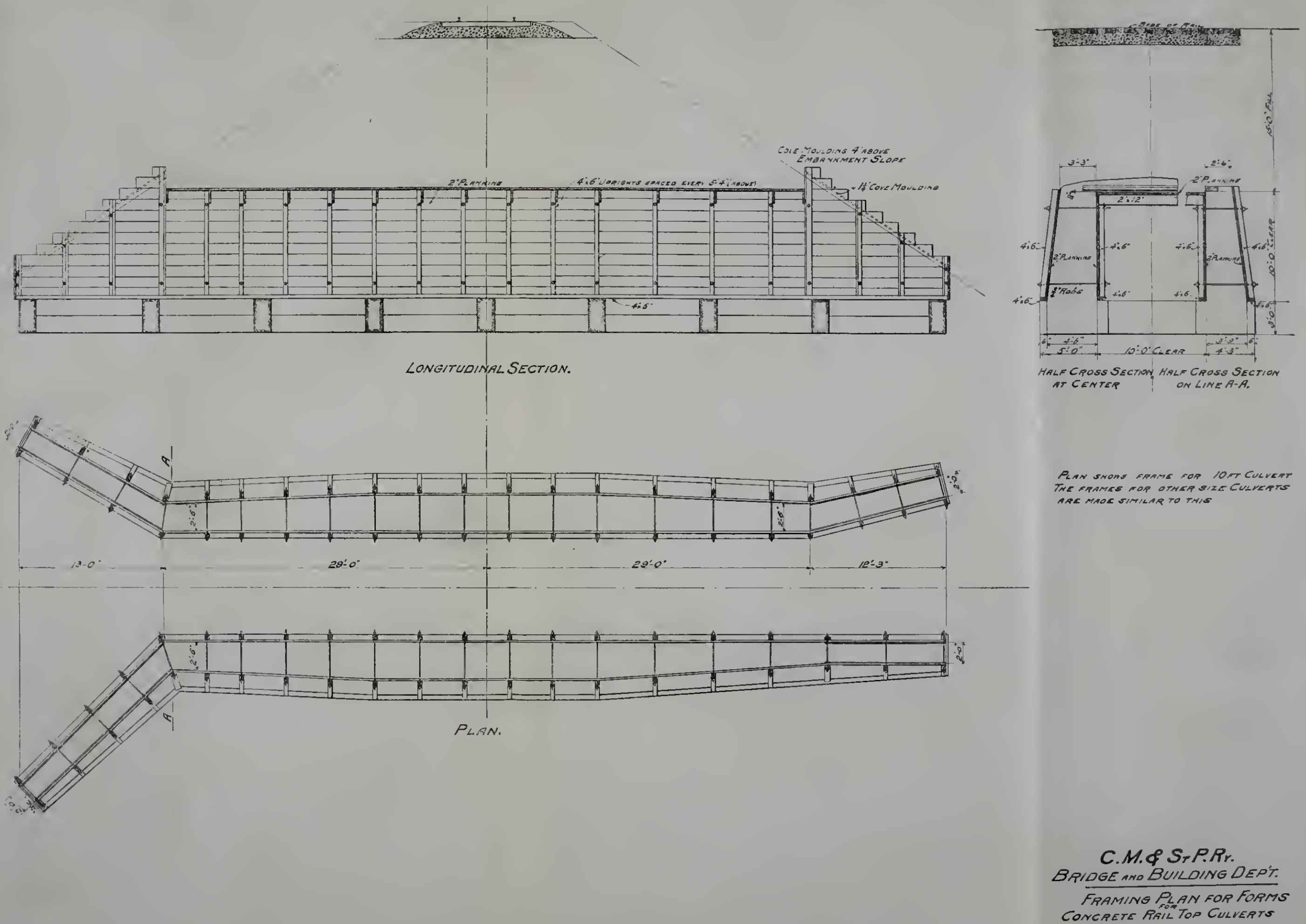
WESTERN SOCIETY OF ENGINEERS.
Vol. VI. No. 1.—FIG. 5.
Reichmann—Rail-Top Culverts.


Cole Moulding 4" above Embankment Slope
2" Planking
4"x6" Uprights spaced every 5'-4" (about)
1¼" Cove Moulding
4x6"
Longitudinal Section.
A
2'-6"
2'-0"
13'-0"
29'-0"
29'-0"
12'-3"
A
2'-6"
2'-0"
Plan.
Base of Rail
15'-0" Fill
3'-3"
2'-6"
2" Planking
2"x12"
4"
4"x6"
2" Planking
¾" Rods
10'-0" Clear
3'-0"
6"
4'-6"
5'-0"
10'-0" Clear
3'-9"
4'-3"
Half Cross Section at Center
Half Cross Section on Line A-A.
Plan shows frame for 10 ft Culvert
The frames for other size Culverts are made similar to this
C.M.& St.P.Ry.
Bridge and Building Dep't.
Framing Plan for Forms for Concrete Rail Top Culverts

It is impossible to compute with any great degree of accuracy the stresses in the culvert cover and walls, owing to the uncertainty of the action of the earth. The earth forms more or less of an arch over the cover, and the cohesion of the earth greatly reduces the lateral thrust against the walls, especially when the bank has once become thoroughly settled. Further, our knowledge about the strength and action of stone, mortar and concrete in a wall is still limited. All the assumptions being made in favor of the structure enables us to reduce the factor of safety and still have a perfectly safe structure. As concrete is now being used very extensively in railroad construction work, and as the same admits of more exact tests, it is to be hoped that in the near future we will be able to tell more about its action in a retaining wall and like structures. If the strength of a wall could be thoroughly established there is little doubt but that we would soon find the action of the earth against it.

Although as stated above, it is difficult to figure these culverts with any degree of accuracy, still it is better to have the judgment guided by calculations in which all the assumptions are on the safe side than to blindly guess at the dimensions of the same.

The walls of a rail top culvert form vertical beams held in position at the top by the cover, and at the bottom by the foundation and transverse walls as shores. In this respect they differ from an ordinary retaining wall, inasmuch as the latter has only one support to hold it in position horizontally, viz., the foundation.

The following notations will be used in the calculations (Fig. 3.):

"P" The lateral thrust, acting normal to the wall, in pounds per running foot of wall.

"H" The clear height of the culvert.

"Q" The pressure per square foot on the bank above the line A B. It includes the weight of the bank and the pressure produced by the train.

"W" The weight of embankment taken as 100 pounds per cubic foot.

"M" The angle which the line A C makes with the horizontal, and is the angle of repose. It was taken as 33° 40′.

"O" The angle the back of the culvert wall makes with the horizontal. In this case 97° 8′, as all the culvert walls were given a batter of 1 in 8.

"Y" The distance of the center of pressure from the top of the masonry wall.

Then, according to the ordinary formula for a retaining wall with a level bank, having a load of Q pounds per square foot on the surface A B, we would have the resultant pressure:

$$P = (\tfrac{1}{2}\ WH^2 + QH)\ \frac{\text{Sin}^2\ \tfrac{1}{2}\ (O - M)}{\text{Sin}\ O\ \text{Sin}^2\ (O + M)}$$

As $M = 33^\circ\ 40'$ and $O = 97^\circ\ 8'$ we have

$$P = .34\ (\tfrac{1}{2}\ WH^2 + QH)$$

and the resultant pressure from the top of the wall is

$$Y = \frac{2WH + 3Q}{3WH + 6Q} H$$

It will be observed that the prism A A¹ B¹ B C is the only portion of the bank producing the lateral thrust.

From the above data the reactions at the top and bottom of the walls and the bending moment of the wall can readily be figured.

The same rules for proportioning a retaining wall, however, can not be applied for the walls of a culvert. In the case of a retaining wall, the thickness of the same is governed by the friction the masonry produces by its own weight. In the case of a retaining wall, failing from the horizontal thrust, it is by sliding along a single plane, or the pressure is greater than the friction and other resistances offered in that plane. However, in a culvert wall it must overcome twice that amount of resistance; or, in other words, the masonry in a retaining wall is subject to single shear, while in a culvert wall the masonry is subject to double shear.

Besides, in a rail top culvert the weight of the bank on top of the culvert materially increases the friction of the masonry, but as the friction is independent of the surfaces of contact, it will be seen that it is impossible to determine the thickness of the culvert walls by this method. It is therefore necessary to figure the bending moment in the walls due to the horizontal thrust of the embankment, and determine the tension on the inner side of the wall, and also the compression due to the vertical load. The algebraic sum of these two must be either equal to zero, or positive; that is, that the compression on the inner side of the wall must be greater than the tension due to the bending moment in order to insure stability.

The culvert walls under high banks might be made thinner than shown in table, were it not for the fact that the trestles are usually filled before the culvert walls have a chance to thoroughly harden.

The table shows the dimensions for the cross sections of the culvert walls with the pressure per square foot on the foundations figured for the footings F, as shown in the table, due to the weight of the bank taken at 100 pounds per cubic foot, and also a train load of 5,000 pounds per linear foot of track, distributed over a distance of 8 feet at the base of rail, and spreading from there laterally at the rate of 6 inches horizontal to 12 inches vertical. The footings are increased or decreased from the table according to requirements. These footings were merely given, and the pressures of the same were figured as a guide to assist the engineers in the field in making their recommendations for the foundations, and also to assist in the office in making the plans of the culverts.

The figuring of the cover F involves many uncertainties, as it is impossible to tell just how the earth acts on top of the cover, and how it distributes the live load over the decking. It will be seen however, that all assumptions were made on the safe side. Mr. Kick, of Prague, Austria, made some experiments to ascertain the distribution of a load upon sand. For this purpose he took a cylinder 10 centimeters in diameter, and placed it upon layers of sand varying from 3.3 to 12 centimeters in height, and found that the pressure was distributed over a circular area, whose diameter was about three times the height of the sand layers. Of course this load is not uniformly distributed, decreasing gradually to zero at the edge.

Professor Winkler, of Berlin, in his book "Vorträge über Brücken Bau," goes into a theoretical treatment of this subject, for ballast floor bridges, figuring merely the frictional resistances of the ballast for the distribution of the load, according to which the load would be distributed over an area of the width and length of the ties, plus .36 of the height of the bank. He then quotes experiments made by Professor Frankel, showing that ballast distributes over an area of the size of the ties plus 2.7 times the height of ballast under the ties. He recommends figuring the distribution over an area equal to the size of the ties plus 1.5 times the height of the bank.

The above indicates to what great extent the cohesion of the earth acts, and it is not unreasonable to believe that its action is equally as great in reducing the earth pressure against a retaining wall. It might not be amiss to consider how the heavy locomotives which are being put into service are going to affect the existing masonry structures on the railroads. Until a few years ago there were few railroads which built bridges for engines heavier than Cooper's Class "A"—extra heavy—which is a 104 ton engine. To-day we see engines going into service weighing 165 tons. Recently the writer computed the stresses in an abutment for an embankment 12 feet high, and compared the stresses produced by Cooper's Class "A"—extra heavy—and a heavy locomotive recently built by the Baldwin Locomotive Works, and found that the lateral thrust was increased about 35 per cent. While the lateral thrust may not be as great as figured, it is not unreasonable to suppose that the percentage of increase of the thrust is nearly correct.

As these culvert deckings are all made of old rails, many of them having their sections greatly reduced by abrasion, it was considered best not to figure too much on the distribution of the live load by the bank, and for that reason the bank was assumed to distribute the live load at the rate of 6 inches horizontally to 12 vertically, 3 inches on each side of the track. Under these assumptions the bending moments of the rails were figured, no allowance being made for the earth forming an arch over the culvert, which otherwise would reduce the effect of the live load.

The permissible fiber stress, per square inch for the rails,—

$$8000\left(1+\frac{\text{Min. stress}}{\text{max. stress}}\right)$$

and no fiber stress to exceed 15,000 ℔s. per square inch.

The footings of the culverts are usually placed on the natural ground. Where this is not hard enough they are placed on a timber grillage extending from one wall to the other, or on piles. The footings, with the exception of a small projection on the outside for the support of the concrete frame, extend entirely on the inside of the culvert, because in this way the greatest benefit of the foundation is derived.

The walls are usually built of a constant cross section, with a batter of one in eight on the back for about ten feet each side of center of the track, and from there both the walls and footings are reduced to the ends, the top of the wall at the end of the wing being made two feet wide as a rule.

The wings of the smaller culverts are usually made straight. On the larger ones they are ordinarily made 15 degrees with the longitudinal axis of the culvert. Sometimes, however, they are made 30 degrees and 45 degrees, as local conditions require. Formerly the wings had steps, but now they are being built parallel with the embankment slope.

The forms used for building the concrete walls, as shown in Fig. 5, are made of 4 inch by 4 inch or 6 inch by 6 inch uprights, and 2 inch by 10 inch planking, surfaced one side and two edges. The uprights are held together with ½ inch or ¾ inch rods. There is a timber decking put on top of these frames, upon which the culvert cover is built. The rails are thoroughly imbedded in concrete to keep them from rusting. The top of the concrete cover is crowned to cause the water to run off freely. The rails are put in the cover in proportion to the load they have to carry, being put closer together under the track and gradually being decreased toward the end of the culvert. Fig. 4. They are spaced in one or two tiers as the length, span and height of bank may require. Under very high fills, old bridge iron is sometimes used along the center of the culvert in place of rails.

The rails extend from one foot to one foot six inches on the culvert walls, according to the size of the culvert.

The larger culverts have their walls built in sections to prevent unsightly cracks from uneven settlement and variations of temperature.

These culverts, as stated before, have concrete struts or shores placed between the footings at intervals of about ten feet, to keep the culvert from washing out, and also to keep the walls from crowding in. The culverts are frequently paved to prevent scour.

These culverts are used quite extensively as farm road crossings and cattle passes.

The rail top culvert possesses the following advantages over an arch:

Its simple design permits its being built by unskilled labor.

It requires no centering, which is quite an expense.

The cover and walls can be more nearly proportioned for the load which they have to sustain.

The strength of the cover, the thickness of the walls and the width of the foundations can readily be reduced toward the end of the culvert.

The effect of uneven settlement of the foundations is less liable to cause injurious effects.

It can be buil tcloser to the base of rail without any risk of failure.

On account of its rectangular shape it affords a better passage for the water.

Its falsework is simple.

DISCUSSION.

Mr. Lee—Mr. Chairman, I think that the details on subjects like this are very valuable to at least some of us. Such culverts are undoubtedly a very economical arrangement, and of course a further extension of the use of concrete, which seems to be very generally coming in on railroads. I have no personal experience in the use of anything of this sort, however.

The Chairman—I would like to ask Mr. Reichmann what is the minimum distance he allows from the top of the rails on the culvert to the base of the track rail? The thickness of the ballast?

Mr. Reichmann—This distance has been made one foot eight inches on rare occasions; however, it is desirable to make it at least two feet or more, as these culverts are usually built under stringer bridges, the floor of which takes up about one foot ten inches.

Mr. Boardman—Where the paving is omitted at the bottom and nothing but cross walls used, isn't there a tendency to scour under those walls?

Mr. Rogers—I think perhaps I can answer that question. During my connection with the St. Paul road we probably built something over 200 rail top culverts, and I don't remember ever having seen but one case where the scour has gone under the cross walls. Of course, that is merely a question of detail. If the walls were not deep enough, the foundations might be scoured out.

Mr. Bainbridge—I would like to ask Mr. Reichmann what quality of cement they used in their concrete, and how much they pay for it?

Mr. Reichmann—As far as paying for it is concerned, I think it is the market price. We have used all brands of cement, some natural cement, but of late Portland cement has been used entirely in all work about the footings.

CXIII.

THE BRIDGEPORT WHEEL PUMPS.

By Ossian Guthrie, M. W. S. E.

Read January 23, 1901.

In connection with the proposition to supply the 39th street and Lawrence avenue conduits with pumps that shall provide a flow of water from Lake Michigan into the South and North Branches of the Chicago River, it has seemed to me that a description of the two wheel pumps formerly used for supplying the Illinois and Michigan canal with a flow from the river would be of use to the public and of interest to the members of the Western Society of Engineers. These pumps, which were in use between 1848 and 1871, under my charge for all but two years of that time, were probably the most economical and efficient device ever tried for raising a large amount of water through a low head.

Credit for the adoption of the wheel pump for supplying the canal is due to the father of the writer, Alfred Guthrie, who was appointed chief engineer of the works, and under whose direction they were erected. In 1846 Mr. Guthrie made a tour of the South and East, inspecting different styles of pumping machinery and consulting with manufacturers as to the practical construction. The Illinois and Michigan canal was the first artificial waterway in this country, if not in the world, to be supplied by steam power.

Between 1848 and 1859–60 only one of the wheel pumps was in use; the rest of the pumping machinery, consisting of four cylinder pumps, each 4.5 feet in diameter, with 6 feet stroke, operated by single engines. The wheel was 32 feet in diameter, with a face 7 feet wide in the clear, dipping in the river 4.5 feet below datum. The pumps were a constant annoyance, chips clogging the valves, or something happening continually to put them out of order, but the wheel was always ready, causing no trouble until 1859 (its 12th year), when trouble began, on account of the natural decay of the wood of which it was built. Up to that time the wheel did practically all the work. The decay began in some of the arms in which heart timber was used; otherwise the wheel remained sound.

During the winter of 1859–60 the works were reconstructed by building two wheels 38 feet in diameter and 10 feet wide in the clear, with 32 buckets having a middle support in the form of a center set of arms and rim to which the bucket supports were attached. These wheels were operated by double engines working at right angles and having eight tons of flywheel in a rim 16 feet in diameter, the pumping wheels having a range of rim travel from 100 feet per minute to possibly 400, showing maximum efficiency, perhaps, at about 250 feet. The range in dip caused by the fluctuations of the lake—between 5 and 9 feet—occasioned no inconvenience whatever, and the range in lift from 8 feet required for purposes of navigation, to 10.5 to 11 feet required to pump the sewage of Chicago, or to supply water power for the Norton mills at Lockport, was only apparent in a more rapidly vanishing coal pile and greater activity on the part of the firemen. The engines were of such capacity and operated with such boiler pressure—125 pounds per square inch—as enabled us to cut off the steam at about 1-6 of the stroke.

Construction of Wheels.

The wheels were built of the best material and with the greatest care. As the details of the construction are so obvious as not to require description, I shall give only such details as apply directly to efficiency. The wheels were lined inside, about ten feet from rim toward the center, with planed and matched plank, and sheathed on the outside with planed and matched material, presenting a perfectly smooth and even surface to the water through which the wheel revolved. The buckets were set at an angle of about 20° from the radial line.

The rim of the wheel was carefully turned, and the concave in which the wheel moved was as carefully finished to the diameter of the wheel. This concave was made adjustable on a horizontal line and the wheel on a vertical line, in such a manner as to permit of very close adjustment. Around the inside of the rim a heavy sole-leather strip was fastened, which served as packing, and thus absolutely preventing any leakage, except between the edge of the bucket and the concave. The concave extended from a point directly under the shaft to the point below the surface of the upper level where the most perfect discharge would be obtained—provisionally a little less than the distance between the buckets. It will be observed that the wheel is about two feet above the foundation, and that no provision is shown for guiding water to the wheel. There arises a question possible of much discussion: How shall the water be delivered to the wheel? As the shortest distance between two points is a straight line, is it not true that the line of least resistance to flow of water will be found close to the shortest line between the bay and the throat of the wheel—assuming, of course, that easy curves may be possible?

Advantages of this Wheel for the Purpose of Elevating Sewage and Storm Water Into the Big Cross Town Tunnels.

It is cheaper of construction than any other device known, and is capable of pumping chips, chunks of wood and rubbish as well, if not better, than any other method; but above any other device, it has peculiar elasticity of operation and adaptation to almost any condition to which any pumping device at these tunnels must be subjected.

As an illustration: Construct wheels of a capacity of 100,000 cubic feet per minute, under normal conditions, and let a heavy rainfall flood them so as to change the dip from 5 to 10 feet; the wheels under such circumstances would go right along, but deliver nearly double the water without additional cost or strain upon the wheel or other machinery—simply increased quantity with correspondingly diminished lift. But again, suppose a greater demand is made; having constructed your plant in expectation of such an event, you have only to notify your fireman, open the throttle and increase the travel of the wheel from 250 to 400 feet per minute. Speaking from the standpoint of 20 years of experience, such elasticity and adaptability is easily within the scope of such a pumping device.

The ability of such wheels to pass rubbish and chunks of wood, almost obviates the necessity of screens and renders it approximately possible to deliver water to within a few feet of the throat of the wheel at the river level. In this respect, there is a great advantage over the centrifugal pumps now in use at Bridgeport, which requires a screen having about three inches clear space between rods. When the water enters the wheel it enters through a wide-open door, and at the discharge it falls down a toboggan slide with an unobstructed outlet, its flow being supplemented by a limited centrifugal force. With the use of a screen there is a considerable loss of head. At Bridgeport from 4 to 12 inches of head is lost through the present screen, causing that much extra lift for the pumps.

The style of wheel pump described was not a novelty when it was adopted for use at the Bridgeport works; it was based on the crude wheel pumps that have been long in use in Holland and Italy, but the idea of applying it was derived by the father of the writer from a similar construction in New Orleans, used for drainage purposes, which he saw on his trip. But these wheels were probably the most efficient ever built, and their record was such as to inspire confidence in their practicability. With the two wheels described 25,000 cubic feet of water per minute was easily lifted through a head varying from 5 to 10 feet, there being practically no loss of efficiency due to breakdown and repairs such as have happened to the present centrifugal pumps at Bridgeport. The cost of the two wheel pumps, and the building now used as an elevator at Bridgeport, was $45,000. At the end of twelve years the wheels were rebuilt and enlarged, making the cost $55,000 more, or an even $100,000 altogether.

When the deep cut in the Summit level of the Illinois and Michigan canal was completed in 1871, pumps were deemed unnecessary under the gravity flow, and the wheels and machinery were sold for junk. In 1880 the deepening of the canal having proved a complete failure, the erection of new pumps was decided upon under the Munn resolution of 1879, and the centrifugal pattern chosen under the mistaken idea that it was more economical than the wheels. The present plant cost $268,000, and the last annual appropriation for its maintenance by the City Council was $121,120. I have no hesitation in saying that I believe it was a great mistake to abandon the wheel type, and that for a purpose similar to supplying the Illinois and Michigan canal, the wheel will prove 50 per cent cheaper than a centrifugal plant in first cost, and will save at least 10 to 25 per cent in maintenance. The present plant does no more work than the old one did, and has been much more expensive in every way.

ABSTRACT OF MINUTES OF THE SOCIETY.

SPECIAL MEETING, December 19, 1900.

A special meeting (437th) of the Society was held in its hall at 8 o'clock, Wednesday evening, Dec. 19, 1900. President A. V. Powell in the Chair. The first paper to be read was prepared by Mr. Paul G. Brown, entitled "Methods of Tunnel and Crib Construction in Chicago." Mr. Brown was present and read his paper. In connection with and illustrating it, were a number of lantern slides. Mr. S. G. Artingstall, who was named in the paper as "the father of the city's improved system of water supply," was called upon but declined to enter into a discussion of the subject at that time. A general discussion was had, Messrs. Reynolds, Brown, Heidenreich, Morehouse and Artingstall participating.

The next paper, "Design for Controlling Works at Chicago end of the Drainage Canal," by Mr. Ossian Guthrie, was read by the author. Lantern slides showing different portions of a model Mr. Guthrie had on the table, were thrown on the screen and explanations made by Mr. Guthrie. The paper and illustrations called out discussions from Messrs. Warder, Seddon, Roemheld and Guthrie.

The meeting adjourned.

ANNUAL MEETING, January 8, 1901.

The 31st annual meeting of the Society was held in the parlors of the Grand Pacific Hotel at 7:15 p. m., January 8, 1901. The meeting was called to order by the President, A. V. Powell, and the report of the judges of the annual election was then read as follows:

JANUARY 8, 1901.

To The Western Society of Engineers:

We, the undersigned Judges of Election, have canvassed the ballots for officers of the Society for the year 1901, and have the honor to report as follows:

Total number of ballots received	196
Total number of ballots rejected	31
Total number of ballots accepted	165
For President, Octave Chanute received	164
For First Vice-Pres., William H. Finley received	112
For First Vice-Pres., Geo. P. Nichols received	52
For Second Vice-Pres., B. E. Grant received	161
For Treasurer, Ralph Modjeski received	164
For Trustee, James J. Reynolds received	164

Yours respectfully,
ANDREWS ALLEN,
JOSIAH GIBSON,
ALBERT REICHMANN,
Judges of Election.

Upon motion, duly seconded and carried, the report was unanimously adopted and the following officers were declared elected for 1901:

President, Octave Chanute.
First Vice-President, W. H. Finley.
Second Vice-President, B. E. Grant.
Treasurer, Ralph Modjeski.
Trustee, James J. Reynolds.

On motion, duly seconded and carried, the regular order of business was suspended. It was further moved, seconded and carried that the reports of the several officers be deferred and printed in the JOURNAL.

The members and the guests then adjourned to the banquet room.

The following are the annual reports showing the condition of the affairs of the Society for the year 1900:

December 31, 1900.

Board of Direction Western Society of Engineers, Chicago:

Gentlemen—I respectfully submit herewith a statement of the Treasurer's account for the year 1900, as follows:

NET RECEIPTS.

Cash balance received from 1899		$2,444.71	
Advertising	$2,157.50		
Entrance fees	354.00		
Journal subscriptions	308.85		
Total dues	4,242.49		
Rent	199.00		
New rooms	362.50		
Interest on deposit in bank	64.67		
Journal sales	179.20		
Sundries	194.25	8,062.46	$10,507.17

NET EXPENDITURES.

Journal, 1898	$ 646.99		
" 1900	1,960.84		
" 1901	1.50		
" Commission account advertising	213.49		
Services	2,298.93		
General printing	414.89		
Stationery and postage	407.52		
Library	231.52		
House expense	1,095.32		
Furniture and fixtures	171.50		
New rooms	357.95		
Sundries	210.57	8,011.02	
One certificate of deposit maturing June 1, 1901	$ 500.00		
" " " " " March 12, 1901	500.00		
" " " " " June 12, 1901	1,000.00		
Cash balance in bank	496.15	2,496.15	10,507.17

Respectfully submitted,

Ralph Modjeski, Treasurer.

Chicago, December 31, 1900.

Board of Direction Western Society of Engineers, Chicago:

Gentlemen—Your committee respectfully submits the following report on the financial condition of the Western Society of Engineers for the year 1900:

BALANCE SHEET.

Resources.			*Liabilities.*	
Cash on hand Dec. 31, 1900		$2,546.15	Bills payable	$ 355.30
Dues 1900 unpaid		295.50	Estimated Journal for December, 1900	600.00
Bills receivable		19.35	Profit and loss	3,991.15
Journal—				
Advertising, 1899,	$185.00			
" 1900,	1,211.00			
Subscription, 1899,	43.20			
" 1900,	46.25	2,085.45		
Journals	600.00			
Total		$4,946.45	Total	$4,946.45

Detailed statement of receipts and expenditures for 1900 is attached.

Of the cash in the hands of the Treasurer $2,000.00 is in the form of interest bearing certificates, drawing 3 per cent.

Respectfully submitted,
Chas. W. Melcher,
Ralph Modjeski, Finance Committee.

RECEIPTS, 1900.

Months, 1900.	Past Dues.	1900 Dues.	Past Sub.	1900 Sub.	Past Advt.	1899 Advt.	1900 Advt.	Entrance Fees.	Rent.	Sales Journal.	Sundries	New Rooms.	Dues 1901.	Total
January	$158.00	$1412.50	$12.00	$ 6.75	$33.00	$294.50	$36.00	$40.00	$28.35	$23.83	$73.50			$2128.43
February	17.50	524.00	8.00	15.75		129.00		21.00	23.85	15.75	.80			845.65
March	7.50	344.98	16.60	105.50	6.00	292.50		74.00	20.85	29.07	5.50		$ 7.50	840.00
April		439.34	4.00	36.00		40.50		25.00	20.85	19.15	12.37	$120.00	5 50	712.71
May		227.18	9.00	22.00		86.50	22.50	35 00	33.41	31.00	16.25	25.00		517.84
June	40.00	109.17		34.00	18.00	96.00		20.00	7 50	2.00	37.50	68.50		412.67
July		272.50		13.75			228.50	15.00	7.50	4.25	60.00	91.00		682.50
August	10.00	102.50		6.00		59.00	66.00	13.00	7.50	6.00	20.65	48.00		338.65
September		71.00	2.00	4.00		36.00	270.50	25.00	7.50	7.25	15.35	5 00		443.60
October		256.50		4.00		53.50	24.00	33.00	7.50	4.65	7.95			391.10
November		62.50		3.50	15.00	23 00	12.00	20.00	20.84	18.35	5.55		2.82	183.26
December		136.50	2.00	4.00			315.50	33.00	13.35	17.90	3.50	5.00	35.00	565.75
	$233.00	$3958.67	$53.60	$255.25	$72.00	$1110.50	$975.00	$354.00	$199.00	$179.20	$258.92	$362.50	$50.82	$8062.46

Cash in hands of Treasurer December 31, 1899....................$2444.71 }
Petty " " Secretary " 31, 1899.................... 50.00 } 2494.71

$10557.17

EXPENDITURES, 1900.

Months, 1900.	Journal 1899.	Journal 1900.	Services.	General Printing.	Sta. and Postage.	House Expense.	Library.	Sundries.	Journal Com'ns.	Furn. and Fixtures.	New Rooms.	1901 Journal.	Total.
January	$ 64.10		$180.85	$ 25.00	$43.19	$ 65.67	$ 34.15	$21.31					$ 434.27
February	76.63		124.55	21.70	24.24	68.89	1.75	6.83					324.59
March	123.37	$ 7.06	88.75	31.20	25.86	76.52	25.12	6.55	$54.12				438.55
April	19.75	32.37	210.92	10.85	35.55	64.15	4.60	7.60		$ 24.00			409.79
May		548.09	206.42	24.40	31.30	119.10	1.60	34.75	74.25	40.00			1079.91
June		116.06	210.67	123.10	82.80	98.10		12.40			$ 46.02		689.15
July		399.66	251.42	97.55	36.43	92.97		26.79			246.40		1151.22
August	363 14	2.93	191.67	4.75	11.61	95.74		5.15			65.53		740.52
September		308.70	191.67	14.60	42.95	91.59	13.50	15.69	85.12				763.82
October		4.60	201.67	35.09	31.89	90.42	5.40	59.70		5.00			433.77
November		518.46	214.67	10.25	16.05	105.91	113.75	4.70		102.50			1086.29
December		22.91	225.67	16.40	25.65	126.26	31.65	9.10				$1.50	459.14
	$646.99	$1960.84	$2298 93	$414.89	$407.52	$1095.32	$231.52	$210.57	$213.49	$171.50	$357.95	$1.50	$8011.02

Cash in hands of Treasurer December 31, 1900....................$2496.15 }
" " Secretary " 31, 1900.................... 50.00 } 2546.15

$10557.17

Chicago, December 31, 1900.

Board of Direction Western Society of Engineers, Chicago:

Gentlemen:—The Auditing Committee desires to report that it has carefully examined the Society's accounts for the year 1900, and finds that they have been accurately and excellently kept by both the Secretary and the Treasurer. All moneys received as per the Secretary's record, have been turned over to the Treasurer, and the expenditures have been duly authorized by the Board of Direction. The balance, as per Treasurer's account, is $2,496. 5, to which should be added $50.00 in the hands of the Secretary for incidental expenses, making a total of $2.546.15 as the amount now on hand.

Respectfully,
Alfred Noble, Chairman.
L. P. Morehouse,
James J. Reynolds,
Auditing Committee.

REPORT OF THE SECRETARY.

Gentlemen--I have the honor to submit the following report for the year 1900 just closed:

TABLE OF MEMBERSHIP CHANGES.

	January, 1900			January 1, 1901.			osses.				Additions.		
	Resident.	Non Resident.	Total.	Resident.	Non Resident.	Tot l.	Transfer.	Resigned	Dropped.	Deaths	ByTransfer.	Elected.	Reinstated.
Hon. Members.....	1	...	1	1	. .	1	..	..	..	..	..	...	..
Active Members....	265	146	411	266	161	427	..	14	6	2	7	28	3
Junior Members....	25	18	43	21	25	46	6	..	1	..	.	10	..
Associate Members	28	1	29	27	2	29	1	1	..	1	..	3	.
	319	165	484	315	188	503	7	15	7	3	7	41	3

A net gain in the membership for the year of 19.

The following are the names of the deceased members:

Active Member, Dankmar Adler, died April 16, 1900.

Active Member, William T. Casgrain, died September 28, 1900.

Associate Member, John H. Esson, died August 23, 1900.

During the year twenty-two meetings have been held in our hall.

The Annual meeting was held in the Grand Pacific Hotel.

The following is a list of papers read and discussions had at the meetings:

Tuesday Evening, January 2, 1900.
Annual Meeting.

Wednesday Evening, January 17, 1900.
A Description of the Opening of the Chicago Drainage Canal, by Geo. M. Wisner.
Discussion--A 175 foot Counter Balanced Plate Girder Swing Bridge.
A Description of the Machinery of the Bridge.

Wednesday Evening, February 7, 1900.
Railroad Preliminary Survey, by Stadia, by John H, Lary.
Discussion on Electrical Underground Construction.
Discharge Measurement of the Niagara River at Buffalo, N. Y.

Wednesday Evening, March 7, 1900.
Are Present Methods of Train Protection Adequate, by Carl E. Davis.

Wednesday Evening, March 21, 1900.
Preservative Treatment of Timber, by Octave Chanute.

Wednesday Evening, April 4, 1900.
Rebuilding of the Kinnickinnic River Swing Bridge on the Chicago & Northwestern R'y at Milwaukee, Wis., by Francis H. Bainbridge.

Wednesday Evening, April 18, 1900.
Discussion—Are Present Methods of Train Protection Adequate, by C. H. Davis.
Discussion on Mr. F. A. Delano's "What Does it Cost to Run Trains at High Speed?"

Wednesday Evening, May 2, 1900.
Parks and Boulevards, by A. C. Schrader.

Wednesday Evening, May 16, 1900.
The New Building for the College of Engineering of the University of Wisconsin, by J. B. Johnson.
Discussion on Mr. O. Chanute's paper on Preservative Treatment of Timber, by S. M. Rowe.

Wednesday Evening, May 18, 1900.
Color Photography, by E. E. Flora and G. A. Douglas.

Wednesday Evening, June 6, 1900.
Monier Construction, by E. L. Heidenreich.

Wednesday Evening, June 13, 1900.
Some Principles Controlling the Deposition of Ores, by Prof. C. R. Van Hise.

Wednesday Evening, June 20, 1900.
Reservoirs of the Lower Mississippi River, by James A. Seddon.

Meetings were not held during July and August.

Wednesday Evening, September 6, 1900
The Efficiency of Small Electric Lighting Plants, by Professors B. V. Swenson and A. W. Richter.

Wednesday Evening, September 19, 1900.
A Supplemental Paper on Monier Constructions, by E. L. Heidenreich.
The Condition of the Water and Power Development in Southern California, by L. K. Sherman.

Wednesday Evening, October 3, 1900.
Proposed Specifications for Steel Railroad Bridges, by J. W. Schaub.

Wednesday Evening, October 17, 1900.
Discussion of Paper, Proposed Specifications for Steel Railroad Bridges.
An Experiment with Wet and Dry Concrete, by Irving Hitz.

Wednesday Evening, October 31, 1900.
Ladies' evening.
Wireless Telegraphy, by W. S. Johnson.

Wednesday Evening, November 7, 1900.
The River and Harbor of Chicago, by R. B. Wilcox.

Wednesday Evening, November 21, 1900.
Further discussion of the paper by R. B. Wilcox, The River and Harbor of Chicago.
The Shop and Laboratory in Relation to Engineering Education, by Prof. Paul M. Chamberlain.

Wednesday Evening, December 5, 1900.
Recent Progress in Sewage Purification, by Prof. A. N. Talbot.
The Robt. A. Waller City Electric Lighting Plant, by E. B. Ellicott, City Electrician.

Wednesday Evening, December 12, 1900.
Additional Discussion of the Paper, by R. B. Wilcox, on The River and Harbor of Chicago.

Wednesday Evening, December 19, 1900.
Methods of Tunnel and Crib Construction in Chicago, by Paul G. Brown.
Design for a Controlling Works at Chicago End of the Drainage Canal, by Ossian Guthrie.

Yours truly,
Nelson L. Litten, Secretary.

December 31, 1900.

Board of Direction Western Society of Engineers, Chicago:

Dear Sirs I have the honor to submit the following report concerning the library to the Society.

During the year the following additions to the library have been made:

Bound books received by purchase	3
Bound books received by exchange and gifts	113
Pamphlets and unbound periodicals as gifts	151
Catalogues	13
Miscellaneous periodicals as gifts	121
New exchanges	18

During the year 62 books have been bound.

Total number of books accessioned to Dec. 31, 1899	3,384
Total number of books accessioned to Dec. 31, 1900	3,623
Increase in number of books accessioned for the year	239

Further attention has been given to putting the contents of the library in the best possible condition for reference, by the employment of an expert librarian who has re-arranged the books and made an entire new set of cards. A set of the "Repertorium des Technischen Journal-Literatur" from 1879 to 1899, a German-English index to current technical literature, has been ordered and will be available in a few weeks.

Yours truly,

Nelson L. Litten,

Librarian.

After the dinner, Mr. Ambrose V. Powell called the meeting to order to hear the report of the Committee on the Paris Exposition.

Mr. Ralph Modjeski reported the committee was not able to make a full report, as it was awaiting the necessary data from Paris; but he made the announcement that the Society had been awarded a silver medal for its exhibit at the Paris Exposition.

This announcement was received with applause.

The retiring President, Mr. Ambrose V. Powell, then delivered his address, as follows:

Fellow Members of the Western Society of Engineers: In compliance with the By-Laws of our Society, it becomes my duty to render to you an account of our stewardship.

The year 1900 was a prosperous one for the Society, and I trust it was equally prosperous for the members, individually.

Our number has increased about 4 per cent, the present membership of the Society being 503, an increase of 19 over the preceding year; 41 new members have been elected. There are, at present, 315 resident and 188 non-resident members of the Society. In addition to these, 11 applications for membership have been favorably acted upon by the Board of Direction. Three members of the Society have been called to join the great majority, during the past year, namely, Mr. Dankmar Adler, April 16; Mr. William T. Casgrain, September 28, and associate member, John H. Esson, August 23.

The financial condition of the Society is good. We are out of debt—excepting the bills for the current month—and have a substantial balance in bank. The finances of the Society have been carefully managed by the Finance Committee and the Treasurer.

The Treasurer's cash balance, at the beginning of the year, was $2,444.71; at the close of the year, it was $2,496.15. Besides this there is in the hands of the Secretary, $50.00 in petty cash account. All bills incurred during the past year have been promptly paid. The total fund handled by the Treasurer, during the year, was $10,507.17. Of the cash on hand, $2,000 is in the form of time certificates, drawing 3 per cent interest This is the first time I believe that an item of interest received has appeared in the Treasurer's account. The balance sheet shows resources and liabilities (not including inventory) of $4,946.45, with $3,991.15 to profit and loss. In this case, the item appears on the right side of the ledger. The total receipts for the year have been $8,062.46, and the expenditures $8,011.02. Full detailed statements of the receipts and expenditures will be found in the report of the Secretary and Treasurer, hereto appended.

During the year, 23 meetings of the Society have been held; 22 for the transaction of the general business of the Society and the reading and discussion of papers, were held in the Society Hall. No meetings were held during the months of July and August. The annual meeting was held at the Grand Pacific Hotel. The meetings have been well attended, and the members have maintained a lively interest in the welfare of the Society. Twenty-four papers have been read before the Society during the year, four of which appeared in the last number of Volume 4. A list of these papers, with the authors, will be found in the report of the Secretary.

The work of the Society has been well performed by the various officers and committees, aided by the members of the Society. Careful attention and much valuable time has been given to this work.

Special thanks are due to the Publication Committee for the efficient manner in which they conducted the JOURNAL. A new departure was made at the beginning of the year, by employing an editor to look after the details of the work. The numbers of the JOURNAL have been issued promptly on time, and the high character of the publication, both as to matter and manner of presentation, has been maintained.

In spite of the hard work done by the Publication Committee, there seems to be a disinclination on the part of the members to write papers for the Society, and I find in looking over the JOURNAL, for the past five years, that it takes the combined efforts of ten members to get one member's name into print. This is not as it should be. Old General Thomas was reported as saying that he would rather fight a battle than write a report of one, and I know that many members of the Society have this feeling. It would be well however, to remember that the easiest, as well as the best way to send your name to posterity, is first do something, then write a report of what you have done for publication in the JOURNAL.

The work of Mr. Nelson L. Litten, Secretary, and Miss Mattie M. Cook, Assistant Secretary, has been faithful and efficient.

In the way of improvements made during the past year, we have enlarged the rooms of the Society, by adding a reading room. This room was furnished at a cost of nearly $400, by voluntary subscriptions from the members.

The rooms of the Society have been kept open from 9 a. m. to 5 p. m., including the noon day hour, and Saturday afternoons until 5 o'clock, excepting for a short time during the vacation period in July. A new typewriter and addressing machine have been purchased, and a telephone has been put in the Society roams.

At the beginning of the year our library contained 3,384 books. The accessions during the year have been 239; the total number of volumes in the library at the present time, 3,623. The library has been entirely re-indexed and catalogued, and in addition to the cards to our own library, we have by exchange, a general index of current engineering literature, fully up to date. Our exchange list now numbers 180 publications, an increase of 18 over last year.

In conclusion, I wish to personally thank the members of the Board of Direction, and the members of the Society, for their support and also their consideration in overlooking the shortcomings of the Chair. I now have the pleasure of transmitting this emblem of the Chair's authority to my successor, Mr. Octave Chanute, a man whose reputation as an engineer is international, a man who has done as much for the advancement of our profession as any man in the country, and in honoring whom the Society honors itself.

Gentlemen, President Chanute.

Mr. Chanute then assumed the Chair and addressed the Society as follows:

ADDRESS OF PRESIDENT-ELECT OCTAVE CHANUTE.

Gentlemen: I feel very grateful to you for the honor you have conferred upon me, an honor most unexpected on my part, and which I feel may be a mistaken one on your part. However, the Vice-Presidents have kindly consented to run the Society, and whatever credit may accrue the coming year, will be due to them. I think the Society is to be congratulated upon the prosperity that has been disclosed by the report of my predecessor, by the renewed interest which has been taken in it by the members of the profession here and by the interest of the public, which has led so many distinguished guests here tonight.

I think it is a most excellent sign of the coming prosperity of the Society that it is taking interest in public affairs, and that it is enabled to secure the presence of the gentlemen who are here.

(Applause.)

I wish to announce that there will be a meeting of the new Board of Direction in the Society rooms on Thursday, the 10th inst., at 1 p. m. The remainder of the exercises tonight will be conducted by your past President, Mr. R. W. Hunt, who is to act as toastmaster.

[The addresses of Capt. Hunt, acting as chairman of the meeting, and of others on the Improvement of the Chicago River, is to be found as the initial article of this number of the JOURNAL.]

Following these addresses, Mr. Chanute again spoke as follows:

Gentlemen, we have heard tonight some very important facts, which appeal to us as engineers and as citizens. We are infinitely obliged to the gentlemen who have brought these facts before us. They require consideration, and I wish to announce that an early opportunity will be taken to continue this discussion at a special meeting of this Society, at which time the technical aspect of the subject will be taken into consideration. I hope that in the meanwhile all of you will be thinking of the subject and preparing yourselves to offer such suggestions and remedies as may seem appropriate.

The Society will stand adjourned.

NELSON L. LITTEN, Secretary.

SPECIAL MEETING, January 23, 1901.

A special meeting (439th) of the Western Society of Engineers was held in their rooms on the 23d of January, 1901. Vice President W. H. Finley in the Chair and about 80 members and guests present. The papers for the evening were: "Northern Pacific Standard Bridge Plans," by Ralph Modjeski, M. W. S. E.; "Rail Top Culverts," by Albert Reichmann, M. W. S. E., and "Bridgeport Wheel Pumps," by Ossian Guthrie, M. W. S. E. Mr. Modjeski's paper having been sent out in advance was not read in full, but some parts were explained by the aid of the lantern slides and the discussion followed by Messrs. Bainbridge, Reichmann, E. H. Lee, H. E. Horton and the Chairman, Mr. Finley. The paper by Mr. Reichmann was read by him and illustrated by lantern slides, followed by a discussion by Messrs. E. H. Lee, Boardman and Rogers.

At the conclusion of the discussion, Mr. Ossian Guthrie read his paper on the "Bridgeport Wheel Pumps," which was illustrated by lantern slides. A lantern slide was also shown of the banquet hall of the Grand Pacific Hotel on the occasion of the annual dinner, Jan. 8, 1901.

On motion, the meeting adjourned at 9:30 p. m.

REGULAR MEETING, February 6, 1901.

A regular meeting (440th) of the Society was held in their rooms on the evening of Feb. 6, 1901. Mr. W. H. Finley, vice president, in the Chair, and about 90 members and guests present. The reading of the minutes of the preceding regular meeting was dispensed with. The report of the Board of Direction on membership was presented, as follows: Petitions for membership, as junior, John F. Icke and William Artingstall; as active members, W. K. Means, Wm. D. Taylor, John McIntyre, Alberto Bement, Wm. H. Pearce, John H. Sutter, Oliver H. Vanderlip and Geo. A. Damon; all of which applications had been referred to the Membership Committee. Also, at the Board of Direction, held February 5, it was moved and carried that three prizes, consisting of medals of equal value, would be given for the best papers submitted to the Society by its members during 1901, on civil, mechanical and electrical engineering.

Under the head of "New Business" the following resolution, introduced by L. E. Cooley, was read by the Secretary:

WHEREAS, Senate bill No. 2330, entitled, "An Act to Authorize the President of the United States to invite the International Congress of Navigation to hold its Ninth Session in Washington, District of Columbia," is now pending in the Committee on Foreign Affairs of the House of Representatives of Congress.

Resolved, That the Western Society of Engineers fully approves the purpose of the bill and believes that the holding of said Congress in the United States will be productive of much good; and,

Resolved, That the Secretary be instructed to communicate the views of this Society to the chairman of the Committee on Foreign Affairs of the House of Representatives.

On motion, duly seconded, the resolution was adopted. The Chairman then introduced Prof. Hermann von Schrenk of St. Louis, who gave a lecture, illustrated by lantern slides, on "Factors which Cause Decay in Wood." Following the very interesting and instructive lecture, a resolution was introduced, which was read by the Secretary, as follows:

WHEREAS, The preservation of our timber supply is a matter of vital importance to the country, and,

WHEREAS, The Secretary of Agriculture has established a Department for the Scientific Microscopic Study of wood decay and the methods of timber preservation; and,

WHEREAS, The subject has been fully presented to the Society by Prof Hermann von Schrenk of St. Louis; therefore, be it

Resolved, That the Western Society of Engineers hereby express their hearty approval and appreciation of this work, and hope that it may be continued and enlarged; and be it further

Resolved, That a copy of these resolutions be spread upon the Minutes and copies be sent to the Secretary of Agriculture, the Director of Plant Industry and the Chief of the Division of Vegetable Physiology and Pathology.

On motion, duly made and seconded, the resolution was adopted by the Society.

Following this, Mr. H. P. Boardman, M. W. S. E., read a paper on "The Substructure of th Glasgow Bridge," which was fully illustrated by lantern slides. As the hour was late there was no discussion on this paper, but before the adjournment a motion was made by J. J. Reynolds, M. W. S. E., that a vote of thanks be given Prof. Hermann von Schrenk for his interesting and instructive lecture, which was duly carried.

The meeting then adjourned at 10:30 p. m.

SPECIAL MEETING, *February 13, 1901.*

The 441st meeting of the Western Society of Engineers (a special meeting) was held Wednesday evening, February 13, in Fullerton Hall, the Art Institute. Vice-President W. H. Finley in the Chair, and 100 members and invited guests present. The paper for the evening was "The Chicago River," by Thos. T. Johnston, M. W. S. E., which was read by the Secretary in the absence of the author. Discussion followed by Messrs. Isham Randolph, E. L. Cooley, Wm. Sooy Smith and Jas. A. Seddon. A number of views along the river, as well as maps of Chicago, Illinois, and the route of the Sanitary Canal, were shown on the screen by the aid of the stereopticon. The hour being late, the Chairman announced that further discussion would be postponed for two weeks; that is, until the evening of Wednesday, February 27.

The meeting then adjourned.

SPECIAL MEETING, *February 20, 1901.*

The special meeting (No. 442d) of the Western Society of Engineers, held Feb. 20, 1901, was called to order by Vice-President B. E. Grant, in the Society rooms, with 55 members and guests present.

Maj. J. B. Long, M. W. S. E., of Princeton, Ill., read his paper on "Concrete Masonry Canal Locks" as built in the Ill. and Miss. Canal, which was illustrated by lantern slides. Discussion followed by Messrs. Warder, Miller, Boardman, Schnable.

The second paper of the evening, by Mr. K. Hellenthal, related to two old bascule bridges as compared with modern practice, which was illustrated by lantern slides. Discussion fellowed by Messrs. Liljencrantz and Reichmann.

The meeting adjourned at 9 : 30 p. m.

J. H. WARDER, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

Bureau of Mines, Toronto, Report 1900.
American Society of Civil Engineers, Catalogue of the Library.
J. H. Warder, Mayor's Annual Message and 24th Annual Report of Department of Public Works, Chicago.
Jeffrey Mfg. Co., Catalogue.
Industrial Water Co., Pure Water for Steam Boilers.
Isthmian Canal Commission, Preliminary Report, Nov. 30, 1900.
International Railway Congress, Bulletin of the.
Canadian Rand Drill Co., The New Shops of the Canadian Rand Drill Company.
W. F. Stanley & Co., Ltd., Catalogue of Instruments.
U. S. Dept. of Agriculture, Bul. No. 21, Two Diseases of Red Cedar.
" " " " " 28, Short Account of the Big Trees of California.
" " " Bul. No. 29, The Forest Nursery.
W. O. Seymour, State of Connecticut, Report of Railroad Comissioners, 1900.
Assn. Civil Engrs. Cornell Univ., Transactions, 1899.
" " " " " 1900.
U. S. Dept. of the Interior, Buls. 163 to 175, U. S. Geological Survey.
" " " " Monograph 39, N. E. & L. E. Coral Faunas of the United States.
Sam'l M. Rowe, C. E., Handbook of Timber Preservation.
Wm. Ford Stanley, Mathematical Drawing and Measuring Instruments.
Smithsonian Institute, Annual Report of Board of Regents, 1898.
U. S. Dept. Agriculture, Duty of Water in the Gallatin Valley.
Agricultural College, Mich., Discussion of Pure Milk Supply.
U. S. War Dept., Report of test of metal, etc., to June 30, 1899.
U. S. Navy Dept., Annual Report of Chief of Bureau of Steam Engineering, 1900.
Street Railway Commission, Report to the City Council of Chicago.
Mass. State Board of Health, Report upon the Discharge of Sewerage in Boston Harbor.
N. E. Coast Inst. Engineers and Shipbuilders, Vol. 16, Transactions 1899–1900.
Societe des Ingenieurs Civils de Francs, Receptions des Deliques des Societes Techniques et Savantes Exposition, 1900.
Elmer L. Corthell, Canals de Acceso Al Puerto Modero, Buenos Ayres, S. A.
Boston Transit Commission, Boston Mass., 6th Annual Report, Boston Transit Commission, Oct. 15, 1900.
Schaeffer & Budenberg, Chicago office, Catalogue of Gauge, Injectors, etc.
Albert H. Scherzer, Scherzer Rolling Lift Bridges.
Wm. S. Bates, The University Geological Survey of Kansas. Vols. 2, 3, 4, 5 and 6.
Index of *Engineering News*, 1890 to 1899, incl. (By purchase.)
Elevation and Stadia Tables, by Davis. John Wiley & Sons, New York.

BOOK NOTES.

Elevation and Stadia Tables, for obtaining differences of altitude, horizontal distances in stadia work, etc., etc., with necessary correction. Also, *Hydraulic Tables*, by Arthur C. Davis, Mem. Am. Soc. C. E. 8vo, cloth, $1.00. Jno. Wiley & Sons, New York.

These tables, by Arthur C. Davis, of the U. S. Geological Survey, will prove a valuable acquisition to the topographical or hydraulic engineer.

One of the tables gives differences of elevation for any distance, for vertical angles up to 15 degrees, including correction for curvature and refraction.

The table for the reduction of stadia readings give differences of elevation for every minute up to 8 degrees and for every five minutes from 8 degrees to 20 degrees.

An unusual and valuable feature is the reduction of slant to horizontal distance, which is given for every 30 minutes.

In the Hydraulic Tables are given velocities of water in feet per second for different values of Kutter's coefficient of roughness from .010 to .035.

The hydraulic radius is varied from 0.25 feet to 25 feet and the slope from 0.264 to 52.80 feet per mile.

These tables will be found invaluable for preliminary estimates on canal or river work where comparison of cost is desired for various cross-sections and slopes, as they obviate the necessity of solving the cumbrous and unwieldy Kutter formula.

W. T. K.

Some Diseases of Wood, As caused by fungi. By Prof. H. von Schrenk.

Bulletin No. 21, U. S. Dept. of Agriculture.—"Two Diseases of Cedar."

Bulletin No. 25, U. S. Dept. of Agriculture—"Some Diseases of New England Conifers."

Bulletin No. 17, Contributions from the Shaw School of Botany, St. Louis.—"A Disease of Black Locust."

These three pamphlets are timely, bearing upon and amplifying the subject of "Factors which Cause Decay in Wood," a lecture recently delivered by Prof. Herman von Schrenk of St. Louis, before the Western Society of Engineers.

These papers are well illustrated and clearly written, so a layman can read them with interest, excepting for the necessary introduction of unfamiliar botanic terms. The conditions under which the several fungi attack the different trees is described and the effect on the substance of the wood by the action of the fungi, is clearly shown by the text and plates. The cure for these evils is not so manifest, for the speedy destruction of all afflicted trees while efficient is hardly practicable, excepting when the woods are under the care of experienced foresters, and there is money available for such work, which will not be remunerative for some years. W.

Annual Report (No. 15) of the Association of Ontario Land Surveyors, 1900, Toronto, Canada, has been received and is in the Library of the Western Society of Engineers. This deserves more attention than simply the announcement in the "Library Notes." It is a well printed 8vo pamphlet of 222 pages, published by the Association in Toronto. The pamphlet contains a short paper on Railway Curves; another on Mining in Ontario; a paper on Bacterial Filtration; two papers on the Yukon country, and Mining regulations there. Then there is a short but clear and valuable paper on a System of Survey as used in the Northwest Territories, which contains some good ideas, but could not be used under the U. S. Land Laws. A paper on Forest Trees of Ontario has a local interest, but the paper on Artesian Wells is more general, and a diagram illustrates the conditions where artesian wells can be used for a water supply. There are two papers on Azimuth by Polaris, which are of special value where surveys are to be made requiring a true meridian, but the mathematics of this paper may be a little discouraging to some. Then there is a short paper on Concrete Culverts, particularly as applicable to highways. W.

Report on the Measurement of the Volume of Streams, and the Flow of Water in the State of New York. Edward A. Bond, State Engineer and Surveyor, Dec. 1900.

This book is of more than local interest, for besides showing by tables and diagrams the actual flow of water of a number of streams in New York State, it explains the method by which the results were obtained. Reference was made to the paper by G. W. Rafter, M. Am. Soc. C. E., on the "Flow of Water over Dams." The use of turbine water wheels, as a gauge of the amount of water supplied to certain water power stations and used by them is novel and seems to have been a desirable check on gauge readings and current meter practice on the same stream. W.

Steel Portland Cement.—Report of the Board of Engineers on this cement as used in the United States locks at Plaquemine, La. War Department Document No. 119. Government Printing Office, Washington, 1900, received from the Chief of Engineers, Brig. Gen. Wilson.

This interesting and valuable report bears upon slag cements, their relation to Portland cements, their composition, character and value, the quality of concrete work, etc., to be had by the use of such cements, etc., etc. Tables of tests of this cement are printed, and from the report this cement appears to be well adapted to certain classes of work, though slag cement should not be called by the name of "Portland." W.

TRADE PUBLICATIONS.

"*The Boiler Maker and Sheet Metal Worker*," published by Jos. T. Ryerson & Son Chicago, has been received for the library.

This is a trade catalogue, containing stock list of boiler materials and illustrations, with price of machinery for boiler makers, etc. The book is of value to mechanical engineers and others interested in the material, design and construction of steam boilers. It contains sundry tables of dimensions and drawings showing rivet spacing for different forms of joints in boiler construction, as also of tube spacing and head bracing for the ordinary horizontal tubular boiler, all of which are valuable. W.

"*Turner Oil Filter and Waste Cleaning Machine*" are described in a small pamphlet issued by M. A. Turner, of Chicago. The object of the oil filter is to remove the dust and grit from oil that has been used as a lubricant, and render it fit to use again. The oil filter consists of a series of chambers containing filtering material through which the oil passes in an upward direction. At the bottom of the chambers water is placed, which can be warmed by steam pipes and through which the oil passes to the filter, thus rendering the oil more liquid. The filtered and purified oil is collected in the final chamber from which it can be drawn as required. The waste cleaning machine is designed to clean the greasy and dirty waste gathered up from about the machinery, engines, etc., and while saving the oil also cleans the waste so it may be used again. It is claimed to be a money-saving machine for large power plants. W.

"*Power and Transmission*," a quarterly review of factory economies and power transmissions, issued by the Dodge Mfg. Co., Mishawaka, Ind. This large 8vo. pamphlet gives illustrations of various forms of rope transmissions, jack shaft construction, coal breaker machinery, etc. There is also some good reading matter pertaining to engine erecting, a modern coal breaker, industrial betterments, etc. W.

PLATE I.

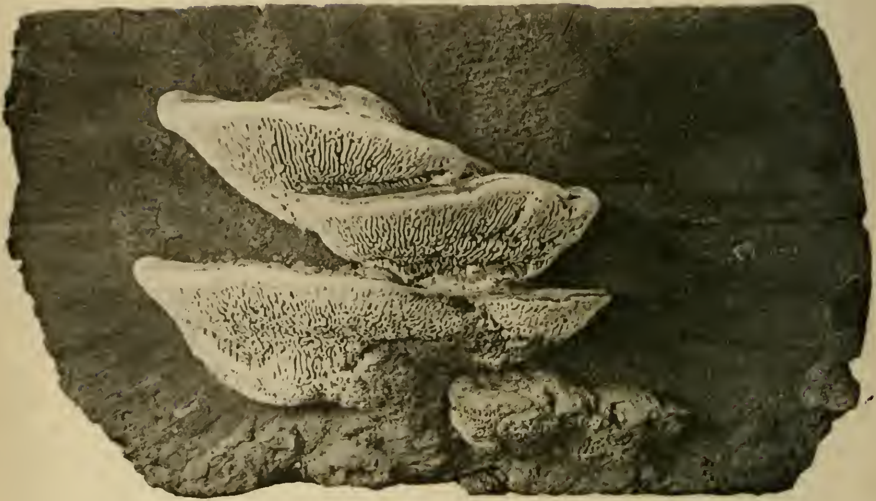


Fig. 1.

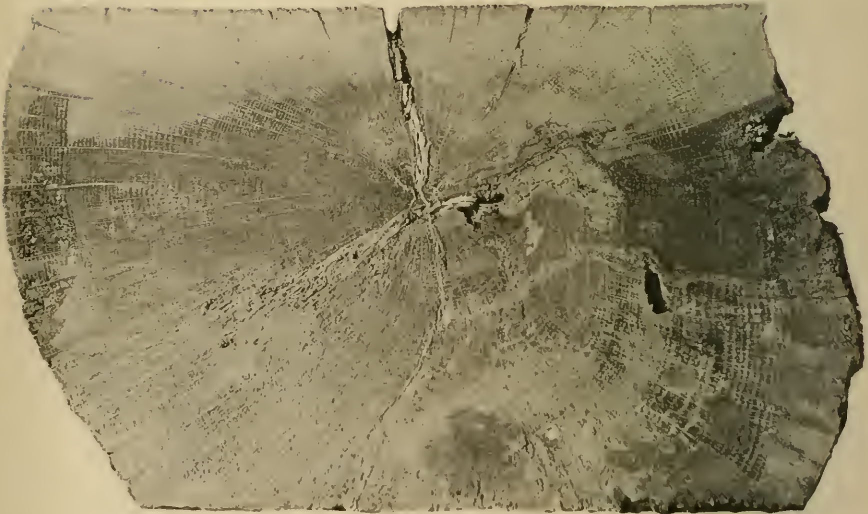


Fig 2.

White oak railway cross tie, decayed by fungus.

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CXIV.

FACTORS WHICH CAUSE THE DECAY OF WOOD.

An Address by Prof. Hermann von Schrenk,

Delivered before the Western Society of Engineers, February 6. 1901.

Mr. President and Gentlemen of the Society: At the outset I wish to express my appreciation of the invitation which has been so cordially extended to me to speak to you this evening on the subject of the decay of timber. To see that the work of the laboratory is of direct practical application is often a source of pleasure to the scientific man.

Before beginning the subject of the talk this evening, I wish to ask for your hearty co-operation in this matter, and likewise for your advice, because we look at the problem, I dare say, from very different points of view; our opinions are likely to clash in some respects, and what the scientific man may see on the one side, may seem practically unfeasible to the engineer. On the other hand, what may seem practicable to the engineer may seem very unfeasible to the scientific man, and unless the two come together and look at the problem from both points of view, we will oftentimes find, as in the present instance, that certain economic problems have cost a great deal of effort and a great deal of money and time to attain results which might have been saved, because of ignorance of some of the fundamental facts that underlie the whole problem. It is to bring some of these facts before you that I wish to address a few remarks to you this evening. I must apologize for the informal manner of presenting these remarks, but urgent business in other parts of the country has prevented me from writing out this talk in a more complete form.

The study of the changes which takes place in wood when it decays was begun many years ago in Europe, particularly in Germany, by the plant pathologists, men interested in the diseases of plants, not only trees, but other plants, who studied the life history of the bacteria and fungi which cause disease. To the workings of the fungi, as I shall attempt to show you, is due the decay which we find in structural timber. During the last three or four years we have undertaken the same line of investigation with reference to the diseases of live trees, and the remarks this evening will be largely based upon investigations made of these diseases, such as their number, their extent and their nature; also of the timber which has been killed by fire or other agencies. These investigations are being made with a view to finding out how such timber might be preserved from the standpoint of the lumberman and forester. The problems and results presented will, therefore, be based largely upon studies from their standpoint, rather than from that of the engineer or constructor, who look at timber as the structural lumber rather than as live matter. But the laws which hold good for live material likewise hold good, to a large extent, for structural material.

The subject will be discussed under several heads for the easier comprehension of the matter in hand. I will consider, first, the structure of wood as such; second, the chemical nature of wood and wood cells; third, the decay of wood; fourth, fungi, what they are and how they live; fifth, the relation of the fungi to structural timber; sixth, the preventive measures in use, and what we may expect of them in future.

First.—The Structure of Wood.

If one examines a longitudinal section of a piece of wood, for instance, a pine stem, one will find that the wood is composed of a series of tubes, which, if closely followed, will be found to end before long in a closed sac. Fig. 6, Plate II, shows you one of these tubular wood cells, or tracheids, as it appears when separated from its neighbors by means of various chemical solvents. The form of these differ with the different kinds of wood; some are larger, some have thicker walls, and a correspondingly smaller cavity. Fig. 12, Plate II, for instance, represents one of the cells from the wood of the locust. Oak tracheids are very similar to this one. You will note that the cells are entirely closed at the ends, and are, therefore, not tubes as we ordinarily use the term. In the piece shown, the cells are empty, that is, they are filled with air. As we approach the ring of wood immediately under the bark in a tree, we would find the newly formed cells filled with various organic substances. As the tree grows older the cells gradually lose their contents; at first the starch products, then the oils, and finally only air is left. The cells which make up the heartwood of a tree contain no living substances, as is sometimes supposed. The so-called "sap" is confined to the outer layers of the tree, and is composed of water holding in solution various organic substances, sugars, starches, oils, etc. We shall see later that it is because of their presence that the sapwood of trees is attacked so much more readily by fungi than the heart wood. One often sees statements in engineering reports which say that the "life is taken out of the wood when it is kiln dried," and others to the same effect. This refers to a number of factors. It sometimes means that the strength is reduced, or the lasting qualities, or some vague qualities which can not be specified. From a biological standpoint the heartwood cells are dead. There may be resinous infiltrations and coloring matter incrusted in the walls of the wood cells, but they have no living contents. When considered from the engineering standpoint they must be regarded as so much dead matter having certain chemical and physical characteristics.

Besides the wood cells extending longitudinally, you will observe certain bands extending at right angles to them. These bands are composed of short, thin-walled cells which retain their living contents much longer than the wood cells. They compose the medullary or pith rays. The cells here are also completely closed. I refer to the fact that the wood cells have no direct communication with each other, because many persons find it difficult to understand why solutions injected into a piece of timber penetrate the latter with so much difficulty. In some kinds of wood direct communication is sometimes established between neighboring cells when the thin membranes which close the small openings in the walls of the cells are broken, but this does not occur with sufficient frequency to be of any importance practically. (At this point a number of slides were shown, illustrating various kinds of wood and several sections of each kind.)

The difference in the character of the different woods is due to the size and arrangements of the various elements composing the wood. The pines and the so-called soft timbers have a marked regular alternation of wood cells of large and of small diameter. Many have special tubes in which resin is secreted. The hard woods, such as oak, hickory, locust, etc., have two distinct forms of wood cells; one kind with very large openings, so large that they are visible to the naked eye, arranged in regular rows or scattered through the annual rings; and a second kind with very thick walls and small openings, making up the greater part of the wood. (Pl. III.)

Chemical Nature of Wood.

We have up to this time considered the parts composing a piece of wood, and it now behooves us to look a little more closely at the individual wood cells. The figure before you (Plate II Fig. 10) shows you a group of wood cells taken from the short leaf yellow pine. I wish to call attention to those which represent the normal wood cells, "w" and "b." You will note that neighboring cells have their walls in common. When the cells are first formed their walls are very thin, and when examined as to their chemical nature it is found that they are composed of a substance called cellulose, the same material which is obtained in the pulp mills when wood pulp is treated to make paper. It is white in color. Very soon after their formation these walls begin to thicken on the inside of each cell, until a thick layer has been added on, so that when viewed at last each wall appears to be made up of three layers—a middle one (the middle lamella), and two adjoining thicker layers. These show plainly in the figure. There are in reality two additional layers which may be ignored for our purposes. The middle lamella becomes infiltrated with lime salts and other products so that it loses its cellulose nature. The basis of the layers added on is likewise cellulose; but they, too, are changed chemically because of the infiltration of complex chemical compounds, which for our purpose we will call lignin. We know that this lignin is made up of a number of complex substances. We find, then, that the walls of the individual cells are bound together firmly; that there are two separate layers, the middle lamella and the added layer on each side, each having distinct chemical properties. The incrusted walls we call wood substance.

Decay of Wood.

During the early parts of the century just passed, the term fermentation was applied to the various processes of decay, rotting, or whatever the dissolution of any organic compound was called. It was supposed that this dissolution was due to a slow process of oxidation, taking place much as in the rusting of iron. It was not until the time of Pasteur that it was discovered that many of these changes, supposed to be caused by fermentation, were, in reality, due to the activity of the lower animals and plants. These induce changes in the organic matter by withdrawing certain substances from it, thus causing it to break down. We now understand by the term decay, a process of breaking down of complex chemical compounds—wood, for instance—into very much simpler ones, because of the activity of lower plants, bacteria and fungi, and lower animals. In other words, we have ceased to believe in the oxidation idea as originally held. We no longer believe that a piece of wood decays because it is alternately exposed to air and water, or simply exposed to one or the other; these changes influence those living organisms which live on the wood, using it for food. The time forbids enlarging upon this important topic, especially as to whether decay is possible without the interference of living things; the weight of evidence at present is decidedly against such an assumption. To repeat, then, by decay we understand changes, chemical changes, induced by living organisms, resulting in simpler substances.

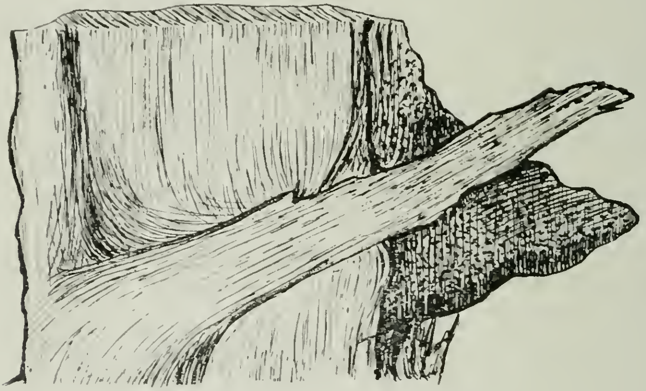
Referring now to wood, we find that the decay of timber is brought about by a number of low plants belonging to the bacteria and fungi, principally the latter. They bring about the changes in the wood substance by excreting certain complex chemical substances known as ferments, a number of which have been isolated. These ferments exert a solvent action on the chemical substance of the walls of the wood cells. The character of this action differs with the fungus which is growing in the wood. Some ferments dissolve out the encrusting lignin, others attack the cellulose. If the encrusting substances are removed the cellulose is left. The figure before you (Plate II, Fig. 10) shows this very plainly. The ferment has in this case dissolved out the lignin, beginning on the inside of each cell, going towards the middle lamella. The latter is finally dissolved, and we have fine white fibers left, which are free from one another. On the table we have some pine wood in which the white holes show plainly where the fungus has dissolved out some of the fibers, leaving others free in the cavities. (Plate II, Fig. 11.)

When the cellulose is dissolved out, a brown charcoal like substance is left, which usually dries out rapidly, causing the mass to appear full of cracks. Plate II, Fig. 13, shows the appearance of spruce wood, with numerous spiral cracks in the wood cells. Pl. II, Fig. 7, shows a few cells from a different kind of wood. Note the crack in the walls and the double crack in the round areas of the two left hand tubes. At "c" a fungus thread has passed through the wall. Fig. 9, Pl. II, shows the gradual way in which the walls become thinner in this process, until finally nothing but the middle lamella is left. This is the commonest form of destruction, seen wherever oak trees and timbers decay. When wet this substance is soft and mushy; when dry it breaks with a bright fracture, and when pressed between the fingers crumbles into the finest powder. Fig. 14, Pl. II, shows still another form of decay. The black lines represent wood fibers. The missing ones have been dissolved out by the fungus threads, some of which are shown between the cells. On Pl. III the gradual destruction of locust wood is shown.

To sum up: The decay of wood is due to the action of fungi, which excrete ferments; these dissolve out certain parts of the walls, and by so doing destroy their physical and chemical properties.

Fungi: What They Are and How They Live.

Fungi are a low class of plants composed of colorless threads which may occur singly, as in the wood cells (Plate II, Fig. 5), or massed together to form sheets or even hard masses, as in the fruiting bodies. Referring now particularly to those which live on timber, they may live entirely in living cells, or they may grow in dead cells of the wood. In both cases we find the cells of the wood filled with many fine threads which penetrate the walls in all directions. They grow longitudinally faster than they do transversely. The threads secrete the ferment already referred to, and this attacks either the living contents of the cells, which usually results in the death of the cell, and ultimately the tree, or what is of more importance to us, the wood fiber. Certain substances are dissolved out which the fungus uses for food. When the cells contain starches or oils, as in the sapwood, the fungus threads flourish, and as a result decay is very rapid, as pointed out. In the heartwood the growth takes place more slowly. In due course of time some of the threads grow out from the wood until they reach the air.



Punk growing around a dead branch.

Here a mere film may form on the surface of the wood, or, again, large masses of threads form complicated structures, usually called toadstools, or those hard brown or black knobs called punks, familiar objects on trees and rotting wood. For a long time these objects were regarded as growing on rotted wood as the results of the decay, and it was not until comparatively recent times that we came to understand that the decay was due to them. From the foregoing you will understand, I trust, that when such a punk apappears on wood it is a sign that such wood is already badly decayed within. The structure of these fruiting bodies is very varied. Before you are some figures which may represent one of the toadstools which destroy many ties in the eastern United States. (Plate II, Fig. 1.) Borne on a stem we see a cap, on the under side of which are numerous plates or gills. In the punks on tree trunks, instead of plates we have tubes, in other cases spines. (See Plate

II, Figs. 2 and 3, Pl. I, Fig. 1.) The surface of these plates, tubes or spines is lined with a layer of threads, which point out at right angles to the plate, tube or spine. Figs. 4 and 8, Plate II, show a small portion of this layer highly magnified. You will see that some of the threads project out somewhat and bear four spines or teeth ; at the end of each tooth is an oval body. These oval bodies are the spores which drop off when ripe, and float away in countless thousands, borne away for miles by the wind. When the spores fall upon a piece of wood, and find proper conditions of moisture and warmth, they sprout and germinate, sending out a thread much like those found in the wood cells. This thread enters the wood and starts to grow in the cells in the manner already described. In the case of living trees they germinate on any wound, dead branch or stub, and the threads then grow down into the heartwood of that tree, causing the changes in the wood already described. The fruiting bodies then form again at that old branch, as you will see in the following photographs. (Here the effect of the fungi on a number of forest trees was shown, also several of the more common fruiting bodies.)

Fungi and Structural Timber.

The growth of fungi on structural timber does not differ materially from that on live timber. The fruiting bodies are familiar sights on railway ties, in mines, in houses, etc. Those growing on railway ties were first studied in this country by Mr. P. H. Dudley many years ago. He collected a large number, but for some reason his labors have not been generally recognized. The frontispiece, Plate I, shows one of the common fungi (Deadalia quercina) found on oak ties in the eastern United States. The pores in which the spores develop can be seen plainly in Fig. 1. The threads have already destroyed a large portion of the tie, as is evident from Fig. 2 of Plate I. The top of the tie is comparatively dry, as it was exposed to the air. The white lines at one side show sheets of the fungus. The rate of growth of the fungus in structural timber differs with the conditions. These have been referred to a number of times, and it may be well to enlarge on this point for a few moments. Moisture is necessary above all, for without water no growth can take place. Absolutely dry wood will not decay, but owing to the attraction which wood has for water this is rarely found. It may, however, be approximated to by free exposure to the air, as was seen in the tie just shown. It is for this reason that timbers of small diameter will last longer than those of larger diameter. Ties may be completely decayed at the bottom and within, while the top is sound. There is no such thing as "dry" rot. This term has been applied to wood destroyed so that a brown brittle wood is left which quickly turns to a dry brittle mass. Air is necessary to allow the growth of the fungus threads. Wood kept absolutely air tight will not decay, as is instanced by wood completely submerged under water. A certain amount of heat is also necessary. In the railroad bed drainage is all important, for in poorly drained land a moist chamber is formed under the tie which favors the growth of the fungus. In mines, where the air is often surcharged with moisture, the conditions for the development of these fungi are excellent ones, the sheets often reach astounding proportions, and attract attention because of their snowy whiteness.

Actual data as to the rate of destruction of wood by these fungi are yet wanting, and in many instances it is very desirable that they be had. This is one of the problems which awaits further attention. The tie shown in Plate I had been in a cinder ballasted roadbed in Maryland about three years.

The fungi which destroy the ties, bridge timbers, etc., are present in the native forests. Every dead tree, branch or stump has a number growing in its wood. (Photographs of several were shown.) The fruiting bodies form on the timbers after a time, and the spores are then carried to the adjoining woods, infecting ties, timbers, etc. Whenever sawed timber is brought from the forest, the spores go with it and grow when placed under favorable conditions. In tracts where forest fires have killed the timber, the dead wood is destroyed in a few years. This ought to be a wholesome object lesson to those who deal with wood. (Photographs were shown of burnt tracts in California, and also one showing how these fungi destroyed almost one-fourth of a red fir trunk, two feet across, in four years.) We can understand, therefore, why an engineer or architect, for selfish reasons alone, should be interested in a conservative business-like forest policy; why they should wish forest fires suppressed, for every dead tree, every decaying log contributes just so much to the distribution of these agents of destruction, offering the food supply which allows them to multiply. They likewise allow boring insects to breed, which help in spreading the fungi by making it easier for them to enter timber and destroy it more rapidly. Instances of this kind are numerous enough, but with our wealth of material we have been slow to realize the meaning and extent of this destruction which is going on, and to urge that steps be taken to prevent it in the future. I wish the time would permit my enlarging on this phase of the forestry question, which is of such significance to all. (A number of slides were then shown which illustrated various forms of decay in structural timber, together with their fruiting organs. A piece of cypress wood was exhibited, taken from the New Orleans Drainage Canal, buried some 17 feet below present Gulf level for several thousand years probably. It illustrated the manner in which wood may be preserved if air is excluded. Photographs of cedar ties were shown, which, although much decayed, were still capable of being used for ties "as long as they held a spike." A large number are now in a section of the track of the Southern Pacific R. R. in Northern California, and have been there for about twenty-one years.)

Preventive Measures.

The point of most importance is the one which deals with the measures taken to prevent the decay which I have described in brief. What are those now used, and in what way are they to be improved upon? Preventive measures may be of two kinds. The first to keep the fungi out of the timber. The second, to make the conditions in the wood such that the fungi threads will not grow there. The first has already been referred to, and it is the second to which we will turn our attention. By practical experience extending over many years, it has been found that wood may be protected more or less by means of various salts forced into the wood at high pressure. A history of those injections was presented in 1885 to the American Society of Civil Engineers at their meeting in New York, and in that report the various methods then in use in this country and abroad were presented and discussed. Subsequently, at meetings of this society and at others, attention was called to the various methods of preservation, particularly the Burnettizing process, the zinc-tannin or "Wellhouse" process, the creosote process, etc. I shall assume that you are familiar with these processes, and shall confine myself to a few remarks as to their bearing on the fungi. It is without doubt true that these salts, one and all, exert a retarding effect on the fungus threads, some more than others, and they continue to do so as long as they are present within the wood, for instance, the railroad tie. Some of them are salts soluble in water, while others are more or less volatile, so that one finds the quantity of injected material materially less at theend of a period of years than it was at the beginning. It may be said, therefore, that to be a perfect impregnating material, the substance injected should not leach out readily. We now know little or nothing as to the time which it takes for the amount of salts in a railroad tie to sink below that point at which it still inhibits the growth of the fungus. Some railroads have kept records, but these are, as a rule, very unreliable. I wish to call particular attention to this fact. If we are ever to find out what the value of a particular process is, and how long it will prolong the life of a piece of wood, we must know beyond any doubt where that piece came from, and how long it has been exposed to certain conditions. It is absolutely necessary that a careful and reliable record of the kind of treatment of a railroad tie, for instance, be kept, together with the date at which the tie was put into the track. That record ought to be such a one that it will last twenty-five to thirty years. The method in vogue at present of stamping the ends of ties with a die, indicating the date of laying, cannot be too strongly condemned. The general manager of a road may object on account of expense when advised to label the ties with a more permanent mark, such as the nails used by Mr. Chanute; but it will be demonstrated before many years are gone by, that the outlay of a few thousand dollars now will save many more before long, because of the exact data which will then be on hand. The supply of available timber is not very large at present, and it will not be long before the railroads in all parts of the country, with a few exceptions, will have to treat their ties. The data collected will then be invaluable. It will not be sufficient to keep these data in one section alone, for with a change in climate, in annual rainfall, in soil conditions, the resisting power, the leaching out of salts, etc., will vary, so that records, to be of any value, must be kept on all parts of a railroad system. Not only should this be done, but ties which are removed from the track should be examined, as will be pointed out.

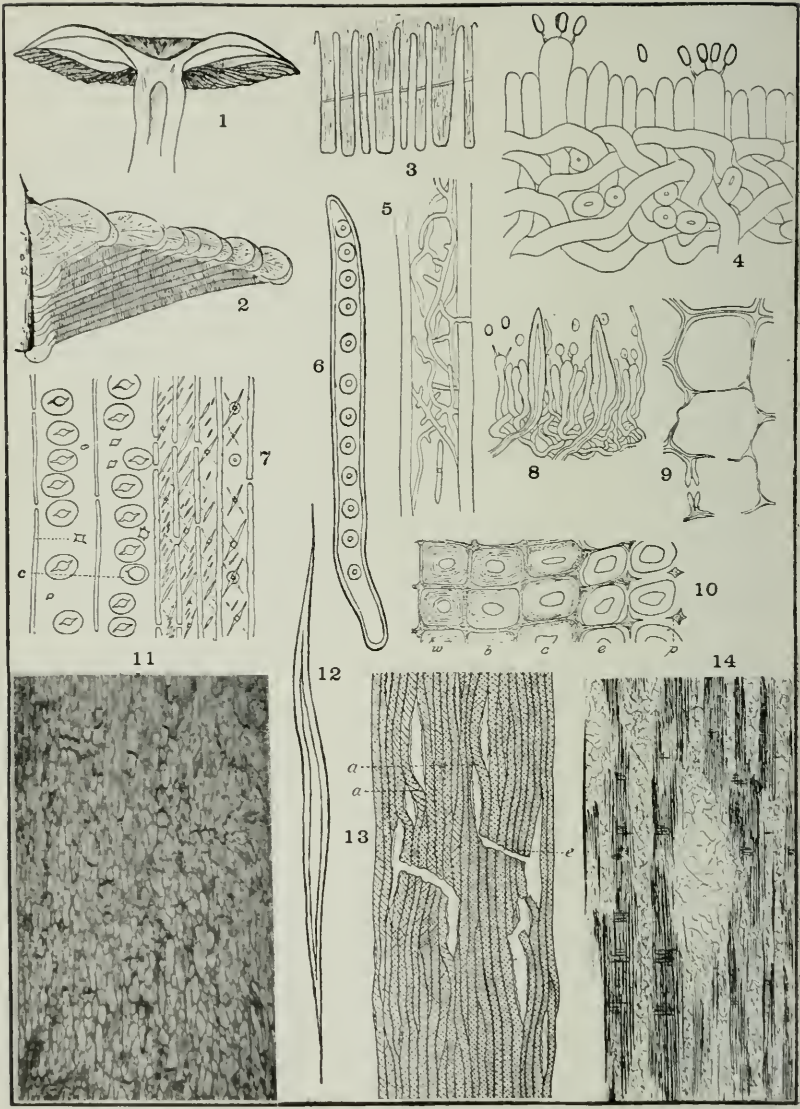
I wish to recall one statement made by Mr. Chanute, to whom all owe a good deal of encouragement, made at the meeting of the American Society of Engineers last October. He says: "The principal dilemma with reference to new processes is that it takes half a business lifetime, 15 or 18 years, to ascertain beyond peradventure whether an antiseptic or a measure is thoroughly efficient to preserve ties in the tracks; yet it may be possible by isolating the bacteria and fungi, which are most destructive to wood, and inoculating the chip and shavings with the cultures to draw some approximate conclusions in the course of a few months." In other words, how can we tell in 2 to 5 years whether a given preservative is going to be efficient in the course of 15 or 20 years, for what Mr. Chanute says of "new processes" applies to all, as far as most of us are concerned in this country. It seems to me that what we must do is to find out what the relation of the agent of decay, i. e., the fungus, is to the antiseptic for a number of years. It is granted that a tie as originally injected will not decay. What then happens to it? The salts or substances change or disappear in the course of time. It is, therefore, necessary for us to determine exactly what these changes are, and to make ties artificially that would represent those 10 or 15 years old in the roadbed. This is a difficult problem, which can only be gotten at by making careful observations, chemical and biological, of a large number of ties to see what are the changes taking place. I use the term "large number" advisedly. It may mean several thousand, for the ties vary so much in the amount of material absorbed that tests of three or three hundred ties have absolutely no value. I would not speak of this if tests of this kind had not actually been made recently and important conclusions drawn from them.

After producing the artificial conditions representing ties of various ages, we then can inoculate these ties and see what is the minimum age at which they are still unaffected by the fungus. Facts which will bear out this record will be obtained from ties actually attacked in the roadbed; these ties should be examined carefully and their chemical condition recorded. Work of this kind is now being done abroad and we ought to do it here. The problem is a very big one, but the matter at stake ought to warrant its being carried out.

It has been suggested that it may be possible in some way to accelerate the action of a fungus, so that instead of decaying a piece of wood in 18 years it would do it in three years. It will be evident, I trust, from what has been said, that this cannot be done, for the action will always be prevented so long as there is a sufficiently large quantity of the antiseptic substance left. The conditions under which the fungi grow best may be brought about, but that would hasten matters very little. It seems, therefore, that the only reliable way to solve the problem will be to follow the suggestion made—to find out what happens to ties in the track, make artificial ones to correspond to various ages, and then inoculate these. Another line of experimentation, which will give even more important data, will be to find such localities in the United States where decay of wood goes on with the greatest rapidity. Timbers and ties should then be treated by the various preservative processes now in use, several thousand of each process. These treated ties, for instance, together with some untreated ones, should be placed side by side in a track, carefully labelled, and examined every year thereafter. One would in that way obtain valuable information as to the relative value of the various kinds of tie treatment. I realize that these suggestions are crude ones, which will have to be modified.

In conclusion I might say that laboratory experiments such as have been conducted, however valuable they may be as indicating the basis of the processes of various kinds, no matter whether you make a hundred inoculations, they are only valuable as indications of what may be expected under actual conditions, so not until you put those in actual practice can you get much satisfaction. Unless we use those ties in the tracks in various parts of the country and experiment with different kinds of treatment, not until then may we expect to realize the results for which we hope.

PLATE II.



Various forms of decayed wood fibre.

*Explanation of Plates.**

Plate I, Fig. 1. End view of an oak tie showing a fungus (Daedalia quercina) growing out from the wood. This tie has been in the track (cinder ballast) for about 3 years.

Fig. 2. View of a similar tie about 6 inches in from the end, showing how far the fungus has decayed the wood. Note the white lines showing where the fungus forms sheets of threads. The whole tie is decayed except the upper two inches.

Plate II, Fig. 1. Mushrooms cut in half, showing stem and plates or gills on which the spores are borne.

Fig. 2. Section of a "punk," showing many layers of pores; only the lowest layer, the last one, is producing spores.

Fig. 3. The holes or pores of a "punk" in which the pores are found more highly magnified than the last.

Fig. 4. Portion of the inner lining of such a tube or pore (as from the plate of a mushroom), showing the large threads with 4 spores at the ends. (Highly magnified.)

Fig. 5. A portion of wood fiber filled with fungus threads, some of which pass through the walls. (Highly magnified.)

Fig. 6. A single wood cell or "tracheid" from pine wood.

Fig. 7. Wood showing cracks formed where the fungus removes certain parts of the walls. (See Fig. 9.)

Fig. 8. A portion of the inner lining of the pores of another fungus different from that shown in Fig. 4.

Fig. 9. Section of three wood cells, showing how the walls gradually become thinner as certain parts are removed by the fungus.

Fig. 10. Section of pine wood, showing gradual changes resulting when a fungus destroys the wood, as shown in Fig. 11. These cells are taken from the edge of a white hole, "w," normal wood cells. Note the middle layer and the two layers added on, "b" and "e," various stages showing how the encrusting substances are dissolved out, leaving the individual fibers free at the extreme right, as "p"

Fig. 11. Wood of balsam fir which has been destroyed by a fungus, leaving it full of white holes.

Fig. 12. Single wood cells from the locust wood. Note its thick walls and small central opening.

Fig. 13. Wood of the spruce, showing spiral cracks in the walls due to shrinking after attack by a fungus. The lens-shaped holes are the places where the medullary rays formerly were. Such wood crumbles into fine dust when compressed.

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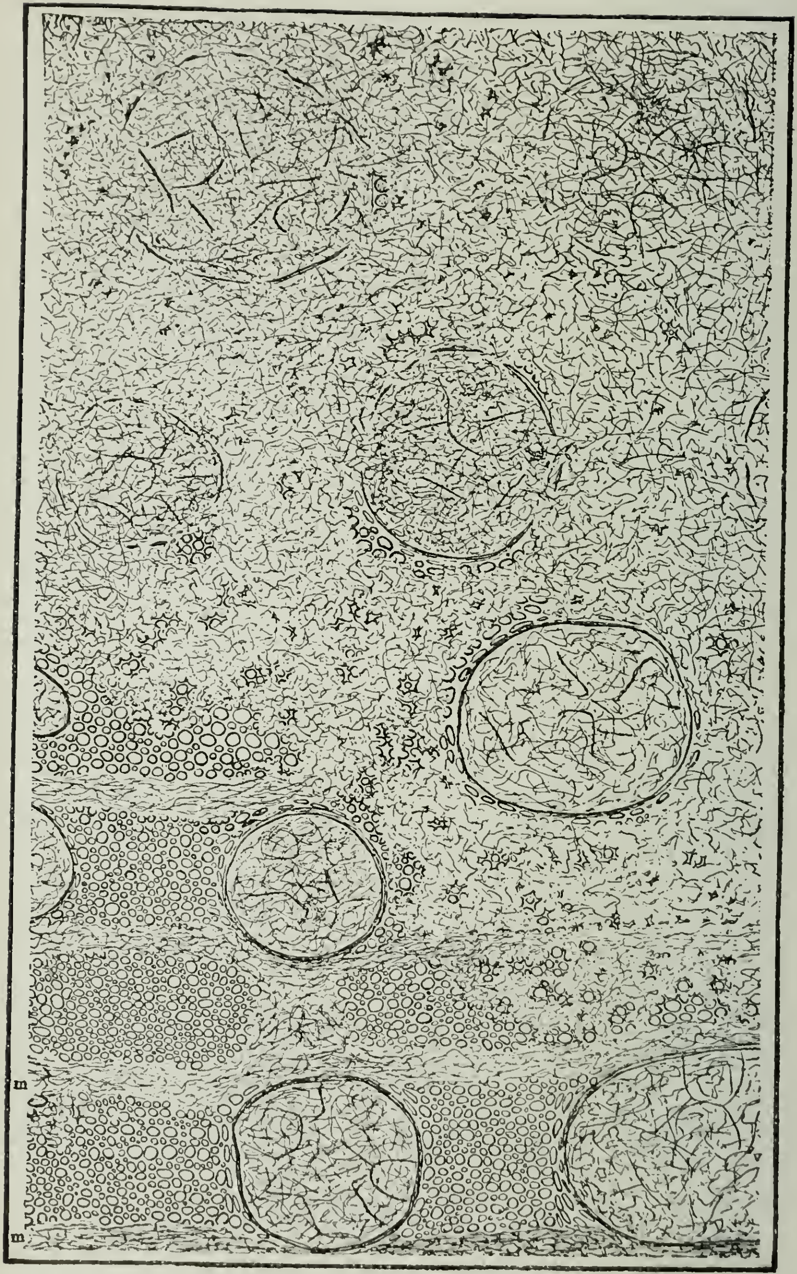
*NOTE.—The figures on Pl. II are, with the exception of Figs. 1, 6 and 12, reproduced from the author's paper on "Diseases of New England Conifers," Bulletin No. 25, Div. Vegetable Physiology and Pathology, U. S. Department of Agriculture, 1900. Pl. III is reproduced by permission from the Twelfth Annual Report of the Missouri Botanical Garden.

PLATE III.



Decay of wood of locust timber.

Fig. 14. Wood of spruce destroyed by a fungus which has eaten out entire masses. The holes are now filled with fungus mycelium.

Plate III. Drawing, showing how a fungus is destroying wood of the locust. Notice the large wood ducts filled with fungus threads in places where the fungus has destroyed the medullary rays.

CXV.

THE SUBSTRUCTURE OF GLASGOW BRIDGE OVER THE MISSOURI RIVER.

By H. P. Boardman, M. W. S. E.

Read February 6, 1901.

The Chicago and Alton railway crosses the Missouri river at Glasgow, Mo., about 100 miles east of Kansas City, on a single track bridge known as Glasgow bridge.

It is a high bridge, with all spans fixed, and the track is about 50 feet above extreme high water.

The old bridge, which has just been replaced by a new one, was built in 1878–79. Of the superstructure the five large spans—each

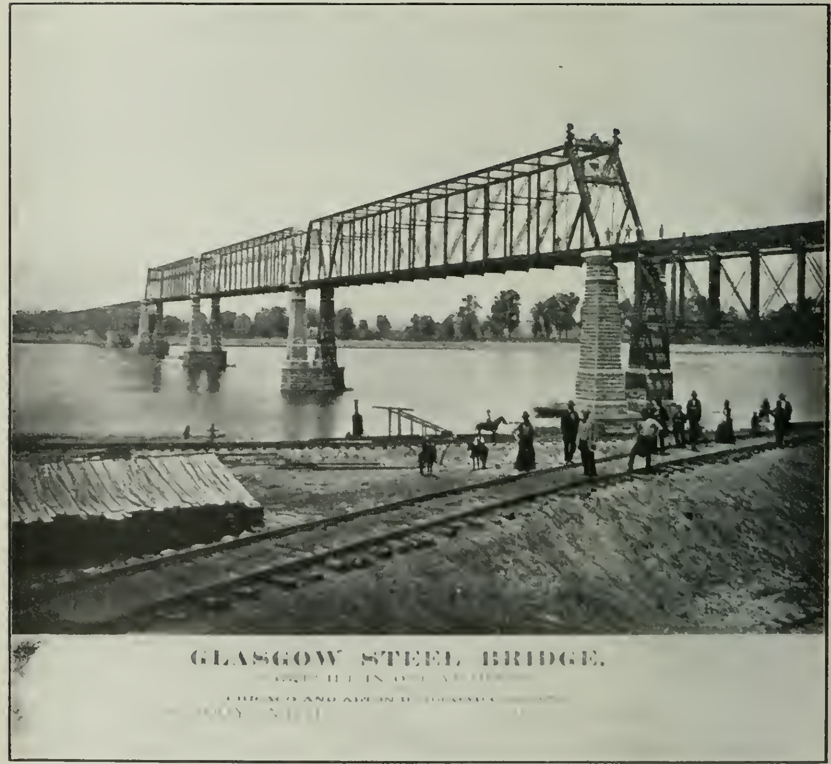


Fig. 1.

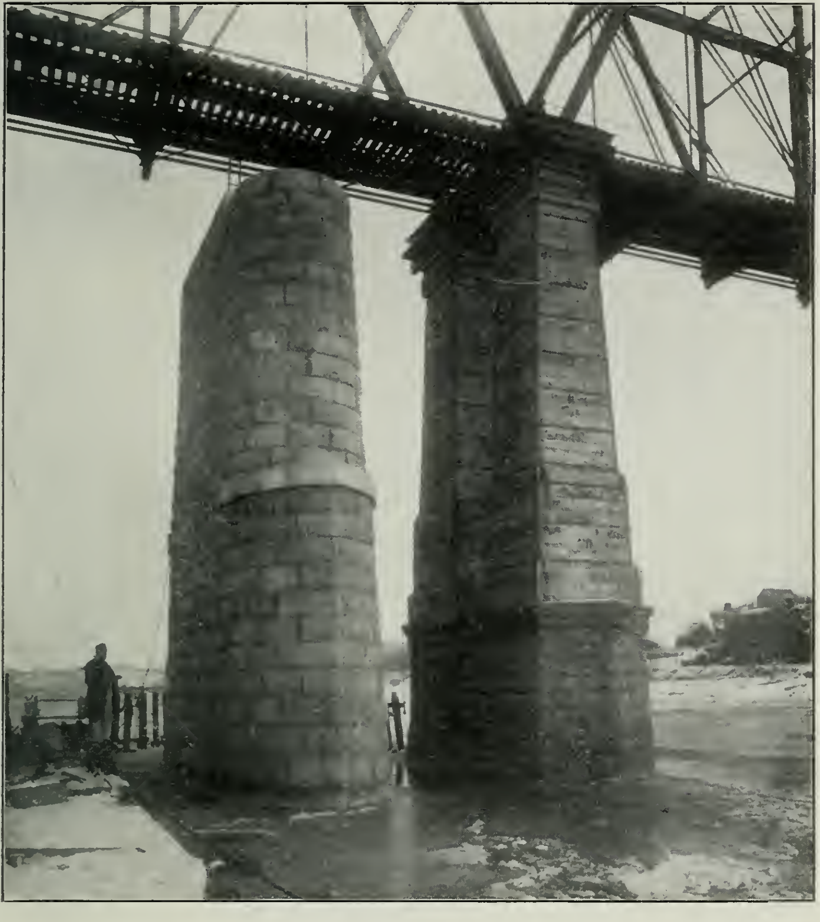


FIG 2.

310 feet 11½ inches center to center of end pins—were the first steel bridge spans built.

Piers 1 to 4, inclusive, of the original substructure were of a rather peculiar style, not exactly like any other bridge piers of which the writer knows. Fig. 1, from a photograph of the old bridge, very clearly shows the style of these piers. The towers, which are 50 feet high, leave the body of the pier 12 feet square, and by offsets and batter reach a minimum of 7 feet square below the ornamental top or coping.

Piers 1 to 6, inclusive, of the original bridge, were all of limestone, and all except piers 1 and 2 were built on pneumatic caisson and crib foundations reaching rock. Pier 2 was built with an open cofferdam, and it caused considerable trouble, as it rested on rock surface dipping to the west. Old drawings on file show cracks that had developed in the body of this pier as early as January, 1881, only two or three years after its completion.

The foundation was evidently deemed insecure, for in 1887 a double walled rectangular pneumatic box caisson was sunk around the pier, and the working chamber, which extended completely around the pier, was sealed with concrete. The water in the annular space between the inner wall of the caisson and the outside of the pier foundation was then pumped out, and this space filled with concrete. Even this reinforcement of the foundation did not prove adequate, and the whole pier was rebuilt in 1894, pier 1 having been rebuilt from an elevation about 15 feet above the crib, or about 4 feet below the ground, in 1893.

The new piers 1 and 2 are of granite to an elevation of 10 feet above that of the tops of the main bodies of the old piers. These new granite piers are surmounted by steel towers about 35 feet high.

One cause for rebuilding piers 1 and 2 was the gradual shattering and destruction of the stone towers of the old piers. This was so serious that each of the towers was reinforced by placing upright angle irons at the corners, and binding around with iron rods tightened by turnbuckles. These tie rods were spaced about 4 feet apart vertically. The coping course was similarly banded with iron straps. This iron reinforcing was placed on piers 1 and 2 in about 1881 or 1882, and on piers 3 and 4 not long after. These iron bands and corner angle irons on old pier 3 are plainly shown in Fig. 2. This photograph also shows the reinforcing of the tops of the towers of this pier, put on early in 1899. It consists of a boxing formed of plates and angles, filled with Portland cement concrete enclosing the tops of the towers, and was considered expedient on account of the cracking and falling away of pieces of the coping.

Pier 4 was topped out with 7 feet 5 inches of steel tower in 1895, and the belt and coping courses of pier 5 were renewed in the same year.

It was decided in 1898 that the superstructure of the bridge should be renewed, since the metal was stressed high by the maximum train loads then passing over it, and much heavier loads were contemplated.

It was not considered advisable to put a new and much heavier superstructure carrying heavier trains on old piers 3 and 4, and early in 1899 plans were made to rebuild these piers after the same general design that had been followed in rebuilding piers 1 and 2. Levels taken at various times indicated a slight settlement of pier 4. It has been asserted that a settlement might have resulted from the compression of timber in the deck of the caisson, there being nine courses of 12 inch by 12 inch timber; but by computation approximately the maximum average load that could ever have come on to this timber deck is a little over 4 tons per square foot, or less than 60 pounds per square inch, which should not materially compress the softest timber. A more likely explanation lies in the fact that the surface of bed rock was uneven, and about one-half of the cutting edge was blocked up on rubble masonry, to save cutting into the rock far enough to give bearing all around. This is clearly shown by Fig. 3 from an old drawing of the caisson as built. It was decided, however, that no further settlement was likely to follow and that new piers 3 and 4 should be built on the old foundations. Plans were made for these piers practically the same as for the new piers 1 and 2, i. e., a solid masonry base surmounted by a steel tower. These plans for new piers 3 and 4 called for all Bedford stone, except for the up-stream faces from point to shoulders, for which granite was specified.

The tops of the old caissons, or more properly cribs, of piers 3 and 4 are five or six feet below mean low water, and it was a question how best to remove the lower courses of the old piers. Fig. 4 shows the partial development of a scheme which was thought feasible and might have been tried had not further changes in plans made it unnecsssary to complete the details. The general scheme was to build a suspended cofferdam surrounding the pier, and lower it to position resting on the ledge or offset projection of the old caisson outside of the footing course. There would have been a space of about 2 feet by 4 feet all the way around between the cofferdam and the caisson, which it was designed to fill with concrete and a mixture of clay and gravel placed in alternating layers by a diver. The pockets in the walls of the cofferdam were to have been filled with puddled clay. Such a cofferdam, when sealed tight, would have permitted the old masonry to have been removed and replaced by new in open air. The most unfavorable aspect of this scheme was the possibility of leakage through the walls of the old caisson below the cofferdam, and thence up and out through the top of the caisson.

Before this plan was completed Messrs. Thomas C. Clarke and Walter Katte were called into consultation to report on a general scheme for rebuilding the bridge. After an examination of existing conditions and approximate comparative estimates, these gentlemen recommended an entirely new bridge on a new alignment alongside the old bridge. This was considered unnecessary and too expensive, since a portion of the substructure of the old bridge was certainly in first-class condition, and seemed too valuable not to be utilized as a part of the new structure. It was, therefore, decided to preserve the same alignment but build new piers to replace old piers 3, 4 and 5.

The combination of a masonry pier and a steel tower for the new piers was ruled out, and a masonry pier for full height was adopted. The old style of unsymmetrical pier, with a heavily battered ice breaker on the up-stream end, not meeting with favor, the old caissons were not considered large enough for new piers of desired size, they being 19 feet 6 inches by 50 feet 10 inches (according to old plans), and located with centers more than 3 feet up-stream from the center line of the bridge.

The general style of pier decided upon was the same as used in the bridges over the Mississippi, Missouri and Ohio rivers, built under Mr. Geo. S. Morison's direction. It is a symmetrical pier, with curve pointed ends from bottom to the starling coping just above extreme high water, and semi-circular ends above that. Fig. 5 shows the general elevations and tabulated general dimensions of all courses of pier 4.

Owing to a change of grade on the bridge the piers were all of slightly different heights. The plans were made alike for all piers from the bottom course to and including course 25, and courses 26 and 27 were made alike for piers 3 and 4. The remaining upper courses were varied as necessary to arrive at the proper elevations on tops of the copings. It was first decided to have the width of copings 10 feet 6 inches over all, and general dimensions of all courses were worked up on this basis. After this had been done, and after plans for up-stream nose stones of courses 1 and 3 had been sent to the granite quarries, the designers of the superstructure asked for a width of 11 feet over all for the coping, and also changed the distance required from base of rail to top of coping, making the piers more than a foot lower than the first design. Rather than change the dimensions for the full height of piers, the additional width desired under the belt course was obtained by making the faces of several courses under the belt course plumb instead of battered ½ inch per foot as they had been designed.

As will be seen by column "W" of the table, Fig. 5, the minimum width under the belt course is approximately 10 feet. In order to have this width exactly 10 feet it would have been necessary to have broken from the batter face to the plumb face part way up on some course instead of at a bad joint. The distance between shoulder points or points of tangency between the straight plane sides and the curved ends is a constant, and equals 25 feet for all courses. The centers for the end curvature below starling coping are at the constant distance of 5 feet 3 inches from the axis of the pier. This was arbitrarily fixed the same as half the width of the coping as originally designed.

The angle at the point between tangents to the curved surfaces varies from about 125½° for course 15 to about 136½° for course 1, being at any elevation just twice the angle Θ.

This column Θ of the tabulation was not very extensively used, though, as will appear later, it was used for purposes of checking in several cases.

Figs. 6 and 6a show samples of the detail plans of the courses. The following method was used in detailing the courses:

On a blue print of the general elevation (Fig. 5) the vertical joints were marked off between the shoulder points, breaking joints at least 15 inches and allowing ½ inch for all joints.

The curved end of each course was drawn to a scale of 1½ inches per foot, and the chord lengths for the different stones determined by scale, two courses being plotted on the same sheet and different colored ink used to distinguish them.

In the cases of two or three courses this method was checked by computation, making use of the angle Θ above referred to, and the maximum error by method of scaling from shoulder to shoulder around the point found to be about ¼ inch.

The interior or backing of these piers is concrete, with the exception of the belt and coping courses, which are of dimension stone throughout. The top coating and starling copings at both up and down stream ends are of granite for all piers. In piers 3 and 4 the up stream stones from shoulders to point are granite for all courses below the starling coping. Pier 5 being practically at the shore line, was designed to have no granite except in copings as above mentioned, but through a misunderstanding the granite quarry people began cutting granite for the first few courses of this pier the same as for the others, so the first three courses contain granite the same as in piers 3 and 4.

All the granite for these piers is Lithonia (Ga.) granite, and cost $26.75 per cubic yard, f. o. b. cars at East St. Louis. All other stone in these piers is Bedford limestone, costing $8.25 per cubic yard, f. o. b. cars East St. Louis.

In cutting the stone the contractor was allowed to vary the horizontal face dimension two or three inches to save waste of stone, provided it did not interfere with the required breaking of joints, and provided the variation was corrected in other stones of the same course, so that total dimensions between controlling points should be correct.

As will be observed from Figs. 6 and 6a, the stones diametrically opposite in any course are alike in dimensions. This saved some work in making plans.

The exposed faces of all granite stones in the copings are bush-mmered, and the granite cutwater below starling copings is fine pointed. The Bedford masonry is rock-faced and a three inch chisel draft was cut at shoulder lines, around the lower edge of the projecting belt course and on the down stream angle below the starling coping.

All vertical joint faces were required to be finished the same as beds for one foot back from face, these joint faces being radical for the curved face stones.

Cramp irons were used across joints between face stones of the coping, belt and first course below the belt, and across the first joint each way from the upstream point of courses 2 to 6 inclusive, and from both up and down stream points of course 16, the starling coping.

The contract for building these piers and their foundations was let August 15th, 1899. The following circular letter sent out for an invitation to bidders will explain the main features of what the contractor was expected to do:

"Appropriate distance bottom of masonry to bed rock 25, 30 and 32 feet respectively" (i. e., for piers 3, 4 and 5). First two piers in channel, the other on shore. About 3,500 cubic yards first-class masonry with concrete backing are to be built in the three piers, for which the railroad company will furnish plans and material ready for use (stone cut ready for laying) on cars at bridge site. For the foundations contractor must furnish all plans, timber and iron, subject to approval, and the railroad company will furnish material for concrete on cars at bridge site. Contractor must furnish all plant necessary for all the work. The railroad company will furnish free transportatioa for men and material over their line. Caissons for channel piers to be grounded on bed rock before starting the masonry. Thickness of solid bed of timber in roof of caissons limited to five feet. Entire top of bearing surface of concrete in air chamber must be rectangular, and not less than 18 by 50 feet. Caissons to be 24 feet by 56 feet over all in plan."

The clause about rectangular bearing between the concrete and the ceiling of the working chamber was intended to rule out the beveled cutting edge as used in many caissons, the chief engineer thinking that this style of caisson might cause a tendency to spread the sides of the caisson apart, due to the wedge action of the concrete filling the working chamber.

A few features of the specifications will be noted:

"No work nor material is to be paid for that does not form a permanent part of the finished piers."

It was specified that the uneven surface of bed rock be blasted out till the cutting edge of the caisson should come to a bearing all around, but the removal of all the bed rock projecting up inside the working chamber was not required.

It was expressly stated that figures given as to depth of bed rock, stages of water, etc., were approximate, and that the contractor must make his own soundings and assume all responsibility as to the success or failure of placing the foundations.

The right was reserved to make any alterations desired in the plans submitted by the contractor for the caisson, either before or after commencement of work, with the provision that if any such alterations materially affected the cost of construction, a proper re-adjustment of prices should be made by the engineer.

Bids were asked and received on the following basis of classification:

1. Price per cubic yard for laying the masonry, including cost of ironing in the pier and of mixing and placing the concrete packing.

2. Price per cubic yard of finished caisson and crib from the level of the seat of masonry to the highest point of bed rock first reached by the cutting edge.

3. Price per cubic yard of finished caisson and crib from the level of the highest point of bed rock first reached by the cutting edge to the level of the cutting edge, when it is sunk far enough into the bed rock to have a uniform bearing all the way around.

The accepted bid was as follows:

1. Laying masonry, $3.00 per cubic yard.

2. Foundation from masonry to point of rock first reached by cutting edge, $12.25 per cubic yard.

3. Foundation from highest point of rock to final elevation of cutting edge, $16.50 per cubic yard.

Fig. 7 shows the general design of the caissons and cribs.

The walls of the caisson proper were composed of an outside course of vertical 12 inch by 12 inch timbers calked, and an inside course of horizontal 12 inch by 12 inch timbers, thoroughly bolted together with screw bolts, all bolt heads and washers being countersunk on the outside.

The deck was composed of three solid courses of 12 inch by 12 inch timbers, the lower two being transverse and the top one longitudinal. This deck rested on the inside horizontal course of the caisson wall and on a 4-inch step offset in the outside vertical course. The bottom of the deck was 7 feet above the cutting edge. The sides and roof of the working chamber were lined with 3-inch dressed plank thoroughly calked. Five cross trusses divided the chamber into six sections as shown. A 2-inch round cross tie rod was placed each side of each truss and two 2-inch round tie rods extended the full length of the caisson.

Above the vertical 12 inch by 12 inch timbers forming the outside wall of the caisson, which were 12 feet long, were the walls of the crib. These crib walls, instead of being solid of 12 inch by 12 inch timbers, were alternate timbers and 12-inch spaces, except where short pieces of 12 x 12 timbers were used as spacers or fillers to receive drift bolts.

Outside sheeting and inside vertical posts and timber crossties served to hold these walls together and fasten them to the caisson below in the manner shown.

The outside sheeting was 3-inch dressed plank spiked on vertically and caulked tight.

It will be seen that much less timber was used than is very often used in similar styles of caissons and cribs, but the results were good, and as a matter of fact the less there is of extra and unnecessary timber the better, for more room is left to be filled with concrete.

The contractor was requested to shoe the cutting edge with 4x6 angle iron, having 6-inch leg vertical and on the outside. It was found to be impossible to get these angle irons in a reasonable time, so they were omitted with the consent of the railroad company, rather than have the work delayed on their account.

The caissons for piers 3 and 4 were built on the east bank of the river, about 1,500 feet north of the bridge. That for pier 5 was built in place, this pier being on shore.

Pier 3 caisson was launched and towed to position September 26, 1899, a false bottom having been put on and calked.

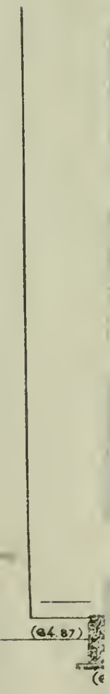
On September 28, before the false bottom had been cut away, the writer took measurements of the immersion and the amount of water in the working chamber, and deduced the following data:

> Amount of water displaced, 4,000 cubic feet, or 250,000 pounds.
>
> Amount of timber in caisson and false bottom, 7,020 cubic feet.
>
> Resulting weight of timber, 35.6 pounds per cubic foot, or 3 pounds per foot, B. M., including all bolts, spikes, drift bolts, tie rods, etc., and whatever moisture the timber had absorbed.

The timber used in building this caisson was mostly white pine, with, perhaps, some hemlock.

It is to be regretted that similar measurements of displacement were not obtained for pier 4 caisson, as yellow pine was used in its construction.

Considerable trouble was experienced in controlling the position of caisson 3 during the sinking. The southwest corner rested on bottom about October 9, while the northeast corner was 15 feet above bottom. For the next week or so the caisson was in very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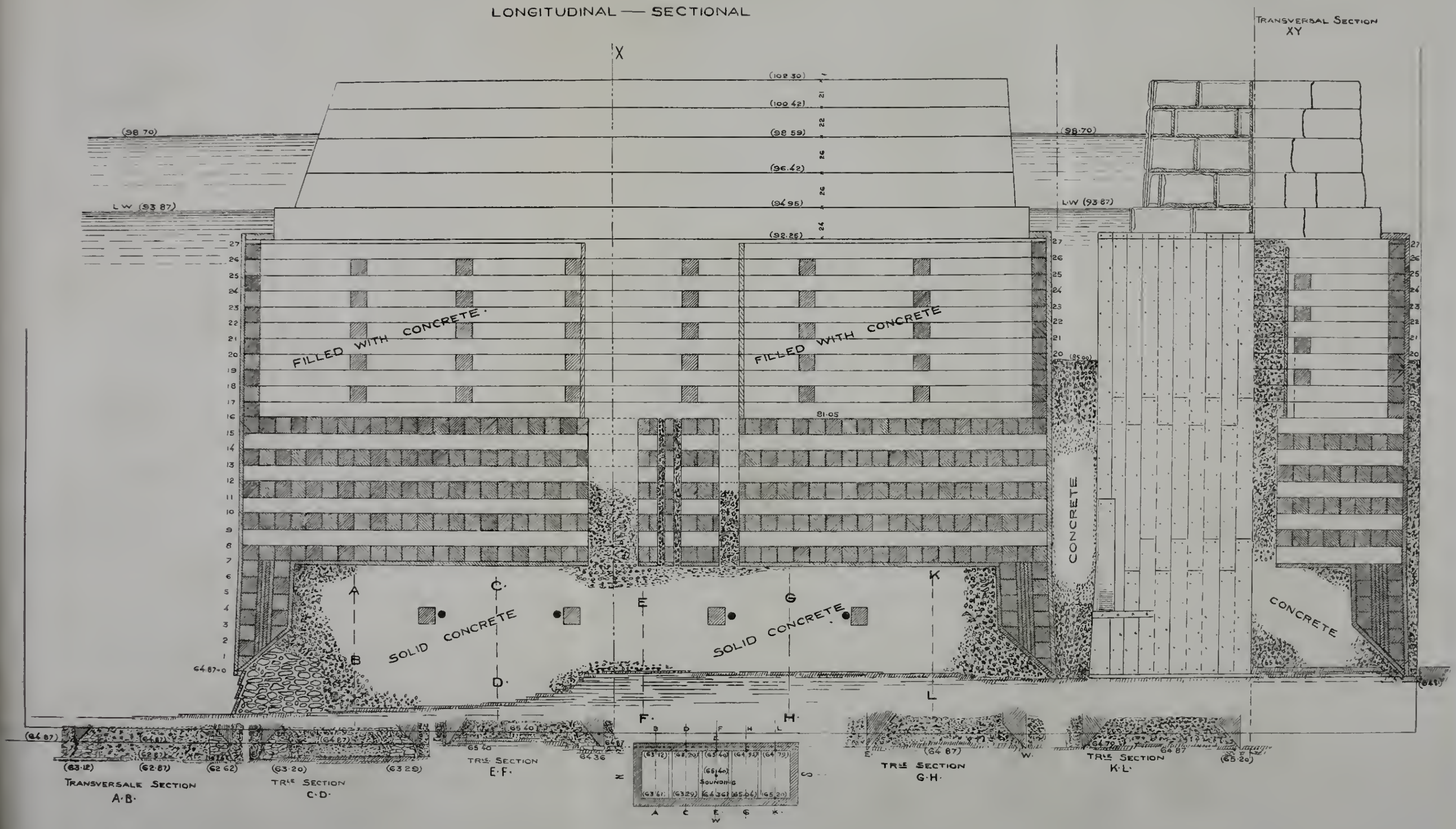
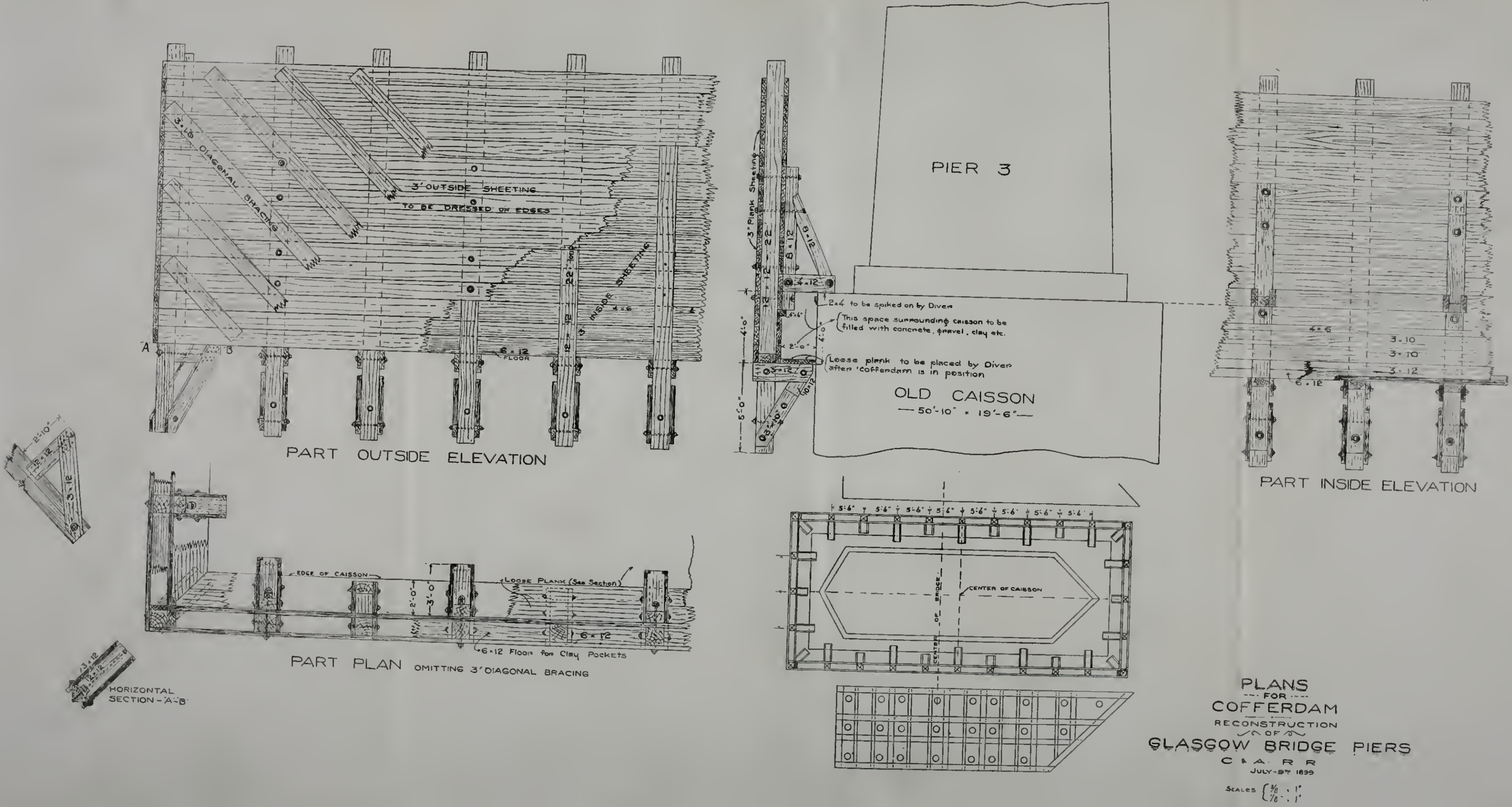
Western Society of Engineers
Vol. VI. No. 2.—Fig. 3.
Boardman—Glasgow Bridge.

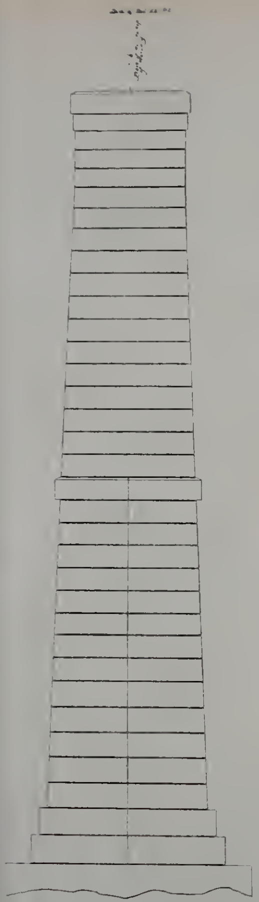


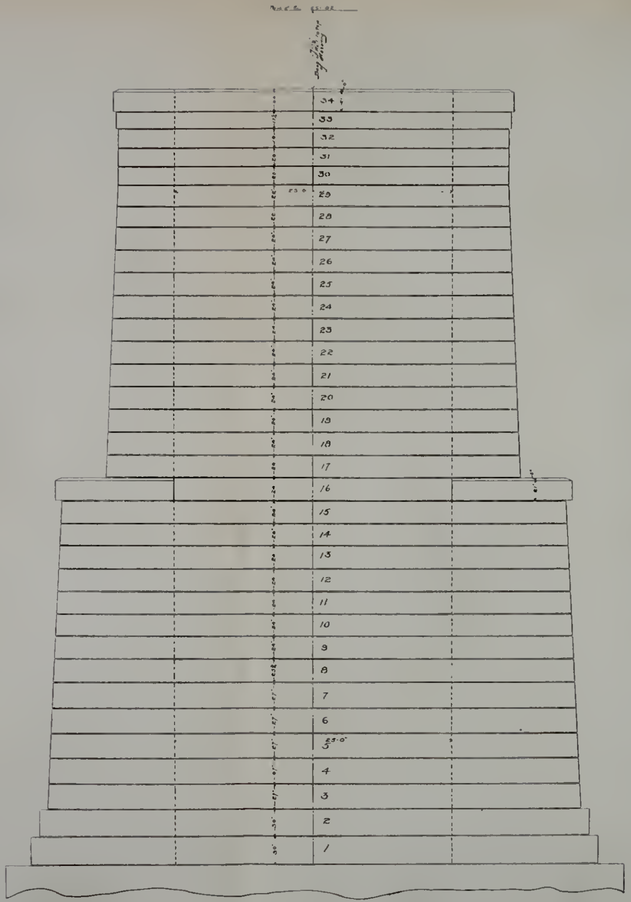


PLANS
FOR
COFFERDAM
RECONSTRUCTION
OF
GLASGOW BRIDGE PIERS
C & A. R R
JULY-8th 1899

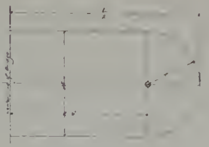
Scales { 3/8" = 1'
1/8" = 1'

WESTERN SOCIETY OF ENGINEERS,
Vol. VI. No. 2.—FIG. 5.
Boardman—Glasgow Bridge.

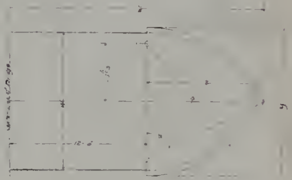




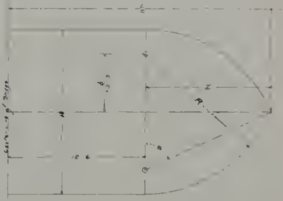
[illegible]	[illegible]	W	T	R	θ	Z	L	Y
34	[illegible]	11 0	5 6				36 0	
33	[illegible]	10 6	5 3				35-6	
32	[illegible]	9'-11½	4-11¾				34-11½	
31	[illegible]	9-11½	4-11¾				34-11½	
30	[illegible]	9-11½	4-11¾				34-11½	
29	[illegible]	10-1⅛	5 0 [illegible]				35 1⅛	
28	[illegible]	10-3	5-1½				35-3	
27	[illegible]	10-4⅜	5-2 3/16				35 4⅜	
26	[illegible]	10-7	5-3½				35-7	
25	[illegible]	10-9	5-4½				35 9	
24	[illegible]	10-11	5-5½				35-11	
23	[illegible]	11-1⅛	5-6 [illegible]				36-1⅛	
22	[illegible]	11-3⅜	5-7 9/16				36-3⅜	
21	[illegible]	11-5⅝	5 8 9/16				36-7⅝	
20	[illegible]	11 7¾	5 [illegible]				36 7⅞	
19	[illegible]	11 9⅞	5 10⅝				36 9⅞	
18	[illegible]	11-11⅞	5-11⅞				36-11⅞	
17	[illegible]	12-1⅞ 12-3⅝	6'-0 [illegible]				37-1⅞ 37 3⅝	
16	[illegible]	12-3⅝		11-11 [illegible]	63°59'40"	10-3⅛	46 6¼	13-3⅝
15	[illegible]	12 5⅜		11-3 7/16	62-46 [illegible]	10 2¼	45-4⅛	
14	[illegible]	12 7½		11-6⅜	62 59 20	10-3⅛	45-7½	
13	[illegible]	12-9½		11-7¾	63 12 20	10 4¾	45 9½	
12	[illegible]	12-11½		11-8¾	63 24 30	10-5⅞	45-11¾	
11	[illegible]	13-1⅝		11-9 13/16	63 37 40	10-7 1/16	46-2⅝	
10	[illegible]	13-3⅜		11 10⅞	63 49 [illegible]	10 8¾	46-4⅜	
9	[illegible]	13-5⅝		11-11 15/16	64 1-10	10-9⅝	46-6⅝	
8	[illegible]	13-7⅜		12-0⅞	[illegible]	10-10⅞	46-8⅜	
7	[illegible]	13-9⅝		12-1 15/16	64 25 30	10-11⅝	46-11¼	
6	[illegible]	14-0⅛		12-3⅛	64 38 [illegible]	11-0 15/16	47 1⅛	
5	[illegible]	14 2½		12-4⅛	64 51 10	11-2⅝	47-4⅛	
4	[illegible]	14-4⅞		12-5⅜	65 3 20	11 3⅞	47-6⅞	
3	[illegible]	14-7⅛ 14'-3⅞		12-6⅝ 12-7⅝	65-15 30 64 27 40	11-4⅝ 11-6	47-9½ 48-0	
2	[illegible]	16-3⅜		13 4¼	66-33 0	12-3 7/16	49 7⅞	
1	[illegible]	17-8⅜		14-1 11/16	68 45 20	10-1 9/16	51-3⅝	
[illegible]	[illegible]	W	T	R	θ	Z	L	Y



COURSES 17-34



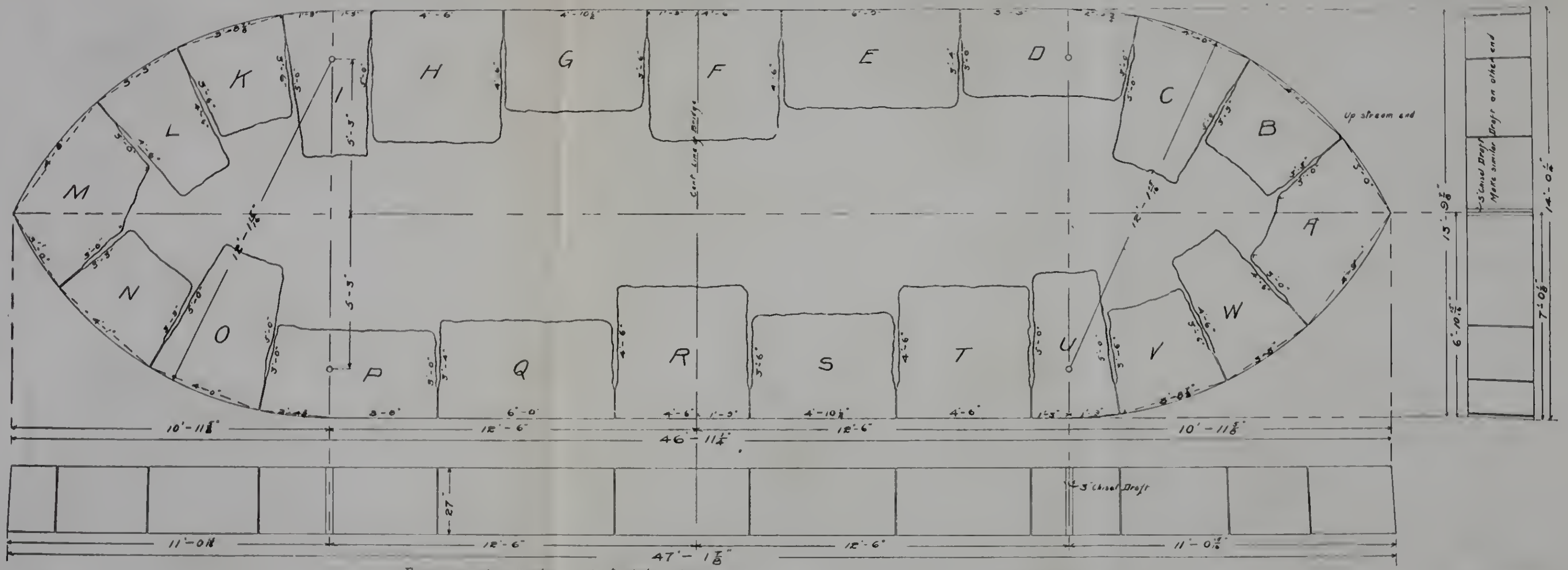
COURSE 16



COURSES 1-15

PIER 4
GLASGOW BRIDGE
GENERAL DIMENSIONS OF ALL COURSES
CHICAGO & ALTON R.R. AUG 31 [illegible]
[illegible]

Western Society of Engineers.
Vol. VI. No. 2.—Fig. 6.
Boardman—Glasgow Bridge.



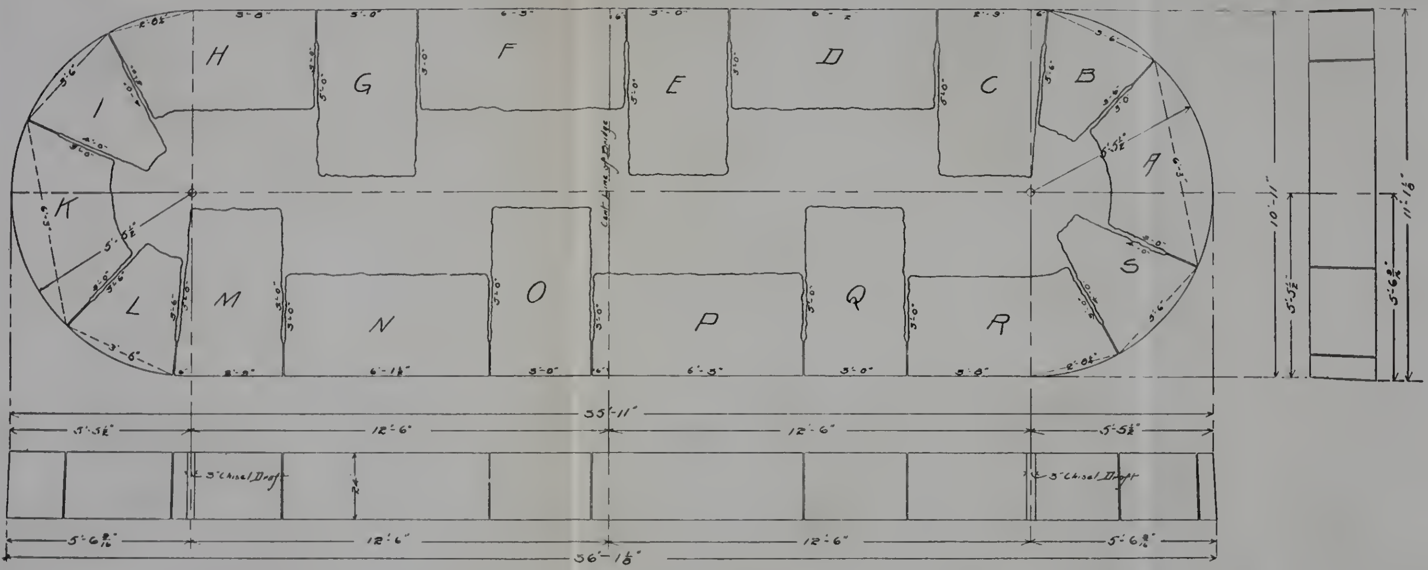
Dimensions shown on plan are for top beds of stones
Batter ⅛" per foot
⅛" allowed for joints
Stones- A, B, C, U, V & W
to be GRANITE in piers 3 & 4

Vertical joints of curved ends to be radial.
and all vertical joint faces to be finished
same as beds for 1'-0" back from exposed face

Mark stones:
3-7-A. 3-7-B / 3-7-C etc. } For pier 3
4-7-A. 4-7-B / 4-7-C etc. } For pier 4.
5-7-A. 5-7-B / 5-7-C etc. } For pier 5.

COURSE 7
NEW PIERS 3 4 & 5
GLASGOW BRIDGE
CHICAGO & ALTON R R AUG 1900
SCALE ¼"=1'

Western Society of Engineers.
Vol. VI, No. 2.—Fig. 6a.
Boardman—Glasgow Bridge



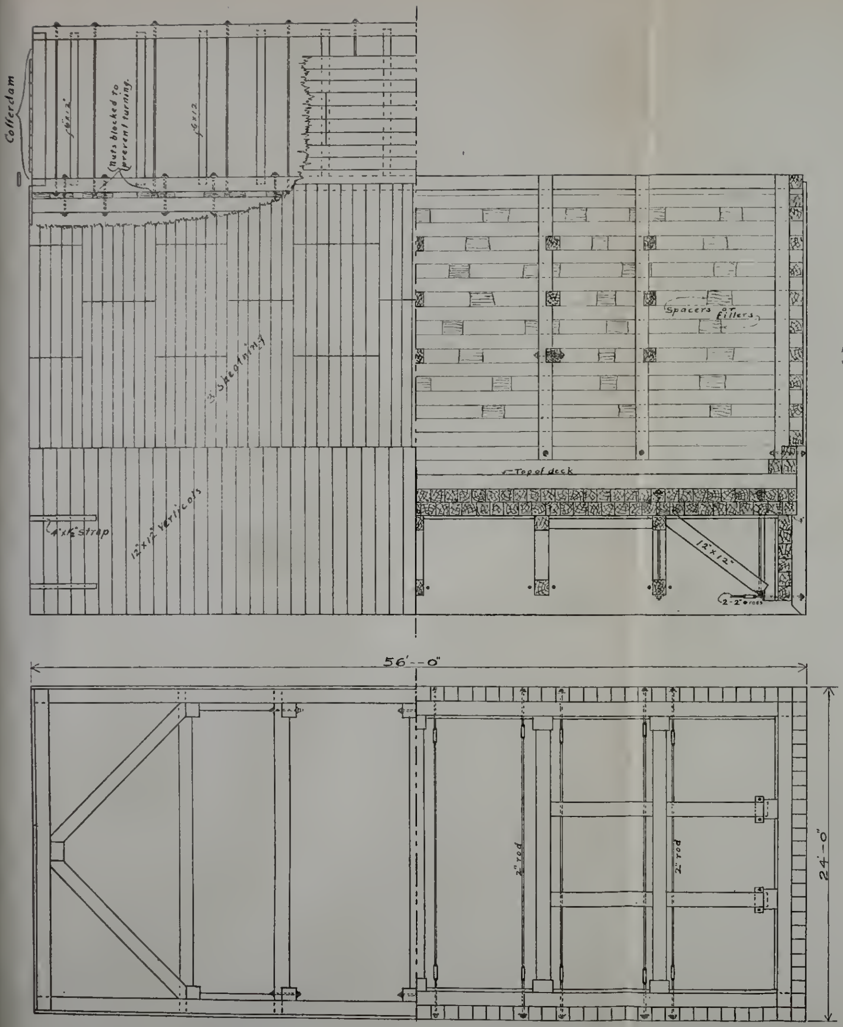
Dimensions shown on plan are for top beds of stones
Batter ½" per foot
½" allowed for joints

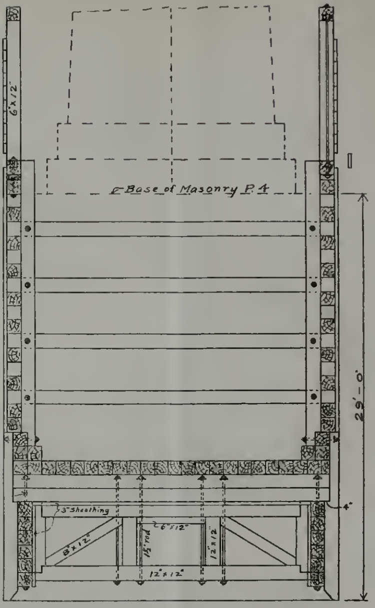
Vertical joints of curved ends to be radial
and all vertical joint faces to be finished
same as beds for 1'-6" back from exposed face

Mark Stones:—
3-24-A 3-24-B } For pier 3
3-24-C etc
4-24-A 4-24-B } For pier 4
4-24-C etc
5-24-A 5-24-B } For pier 5
5-24-C etc

COURSE 24
NEW PIERS 3, 4 & 5
GLASGOW BRIDGE
CHICAGO & ALTON R.R. AUG 1899
SCALE ¼"=1'

6"x12"





This plank placed last and fastened without spikes.

The whole structure firmly fastened together with ⅞" drift and screw bolts.

1½" rods placed each side of each truss.

The cutting edge brought to a rock bearing all the way round by blasting out the unearen rock elevations.

CHICAGO & ALTON RY.
GLASGOW BRIDGE
CAISSONS FOR PIERS 3-4 & 5
BUILT IN 1899

unstable equilibrium, tipping first this way and then that. By the 19th it was well into the sand all around, but was about 22 inches too far north or up stream, 11 inches too far east at the north end and 17 inches too far east at the south end.

The difficulties in controlling this caisson were caused largely by the uneven and shifting bottom upon which it landed, and the strong southerly winds which blew almost constantly while the caisson was in this unstable position.

Sacks filled with earth had been thrown in to even up the bottom under the cutting edge, and the attempt was made to control the sinking by properly placing the concrete filling in the crib. The sinking foreman said the upstream cutting edge landed on the sacks of earth above referred to and clung to them like rubber, resisting the efforts to work the caisson back to correct position.

October 30, after part of the rock excavation had been completed, a determined effort was made to move the caisson by applying jacks to the inside of the cutting edge both down stream and west side, and at the same time jetting was vigorously carried on from the outside to loosen up the sand. No perceptible movement resulted and none was expected, for the estimated total weight of caisson, crib and concrete then in place was about 285 tons more than the weight of the water displaced, and a removal of more than 3 feet of concrete would probably have been required before lateral movement could have been accomplished.

There remained room upon which to lay off the bottom course of masonry, except that the down stream nose crowded the crib timbers.

Computations were made which showed that the moment of stability about the down stream cutting edge of this pier, when built and carrying its share of the new bridge, would be more than four times any overturning moment to which it would ever be likely to be exposed.

In view of these facts it was decided to accept the caisson in its eccentric position.

The cutting edge having been brought to a rock bearing all around, with the exception of a few feet near the northwest corner, the sealing of the working chamber with concrete was begun November 7th and completed in 71 hours of continuous work.

The deck of this caisson was thoroughly grouted with 1 to 1 mortar, composed of 20 barrels of Empire Portland cement and 20 barrels of sand. The first three feet above the deck and also the three feet just below the masonry were of Portland cement concrete. All intervening was natural cement concrete.

It was thought the Portland cement concrete would add strength to the deck of the caisson, if such additional strength were required before the working chamber was concreted.

Several different proportions were tried in this crib, but the ones finally adopted and used throughout the remainder of the work were 1 cement, 2 sand, 4 gravel and 3 broken stone for Portland cement, and 1 ½ cement, 1 sand, 3 gravel and 2 broken stone for natural cement.

The gravel used was about .3 sand that would pass a ¼ inch screen, and the broken stone was crusher-run, screened free of all that passed a ¾ inch screen. Both gravel and stone contained many pretty good sized pieces of about 20 to 40 cubic inches. These coarse pieces had a tendency to separate from the finer materials when a batch was dumped, and I think it more difficult to get solid concrete, free from voids, with such aggregate, than with a finer grade of stone or gravel.

Since the final elevation of the top of concrete in the crib was several feet below water, and since the masonry of pier 3 was not started until sinking had been completed, it was necessary to extend the height of the crib by a temporary cofferdam. The manner of attaching this cofferdam to the crib is shown in Fig. 8, where 6-inch by 12-inch vertical timbers were mortised into the top 12-inch by 12-inch timbers of the crib, and also into a 12-inch by 12-inch cap on top of them. The top 12 inches by 12 inches of the crib

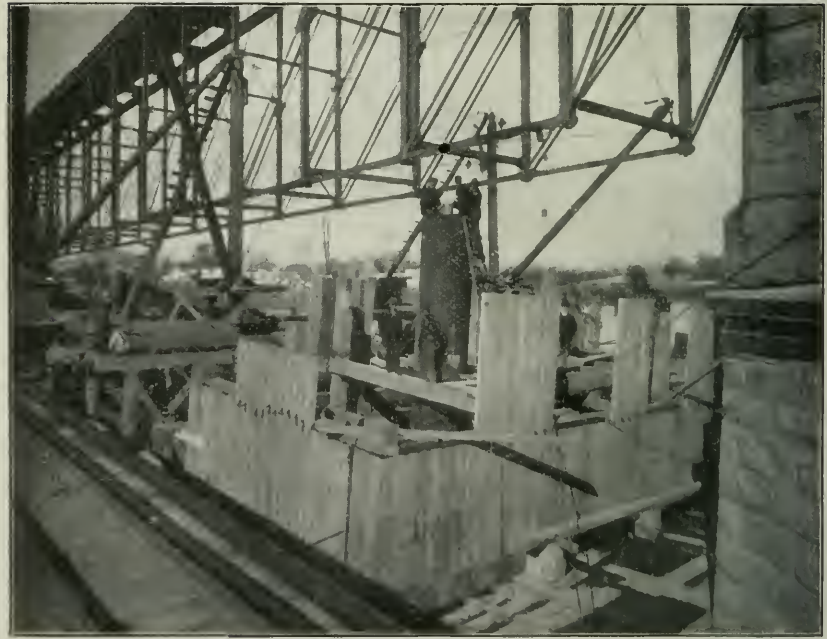


FIG. 8.

was separated from the 12-inches by 12-inches next below by a space of about 4 inches. The two were fastened together by bolts, and the cofferdam was held to the crib by long vertical rods passing down through this upper 12 inches by 12 inches of the crib. The nuts on the bottom were blocked in the space between the two 12-inch by 12-inch timbers, so that by unscrewing the rods from the top, the whole cofferdam would be separated from the crib. In this manner the cofferdam was floated away from pier 3 in four pieces and used over again on pier 4, where it was left in place at the request of the railroad company for use in supporting the false work.

Before caisson 4 was launched, considerable work had to be done preparing to receive it. The piles upon which was founded the false work for supporting the ends of the spans next to old pier 4, when the steel top was put on that pier in 1895, had been cut off at about low water instead of being pulled. Fifty-three of these old piles were found and pulled to clear the way for the new caisson. Considerable rip-rap was also removed with a clam-shell dredge.

Less difficulty was experienced with the sinking of caisson 4 than with 3, and it appeared much nearer its correct position, being no more than six or eight inches out in any direction when sinking was completed.

This caisson had to be forced through much more material than caisson 3, so it was necessary to place all the concrete in the crib and start the masonry to give weight to aid in the sinking. Two courses of masonry was sufficient. The working chamber of 4 was sealed up in fifty-six hours—December 6th to 8th—after having been brought to a rock bearing all around.

The caisson for 5 was built in place with the cutting edge just above the water after leveling off the bank. This caisson was calked only on the inside of the working chamber, and the outside sheeting of the crib was not calked, the concrete and, later on, the masonry being always kept above water line during the sinking.

In piers 4 and 5, it being necessary to begin laying masonry before sinking was completed, it was desirable to know at what elevation the cutting edge would stop. This information was obtained by sounding with a gas pipe jetted down. Such soundings were taken to rock at the corners and several points between, and the lowest elevation of rock found was made the final elevation of the cutting edge. The distances from point of rock first reached to final elevation of cutting edge were 2.97 feet, 2.37 feet and 2.78 feet for piers 3, 4 and 5 respectively. The depths from base of masonry to final elevation of cutting edge were 28.8 feet, 29.0 feet and 30.7 feet respectively. The maximum immersion of cutting edge was about 42 feet for pier 4.

The air locks used were of the Moran type, in which the material bucket is lowered and raised through the shaft by an outside derrick, the wire cable playing through a stuffing box in the center of the outer lock door, which consists of two semi-circular leaves coming together around this stuffing box.

For piers 3 and 5, a combination shaft was used, oval in shape and about 4 by 7 feet in plan. It included both material and man shafts and locks. Below the air locks the material and man shafts were separated only by open iron work, so that it was not comfortable for a man to be climbing the ladder when a batch of concrete was dumped down the material shaft.

In caisson 4 two separate circular shafts about 4 feet in diameter were used.

As usual, when the material would permit, it was blown out. The blow-out pipes and air-admission pipes were 4 inches in diameter.

Candles were used to illuminate the working chamber of caisson 3, but incandescent electric lights were used in caissons 4 and 5.

The rock upon which these piers are founded is a fine grained micaceous sandstone.

Fig. 8 is from a photograph showing caisson 4 during the sinking.

Fig. 9 is a plat showing the general layout of the work and the

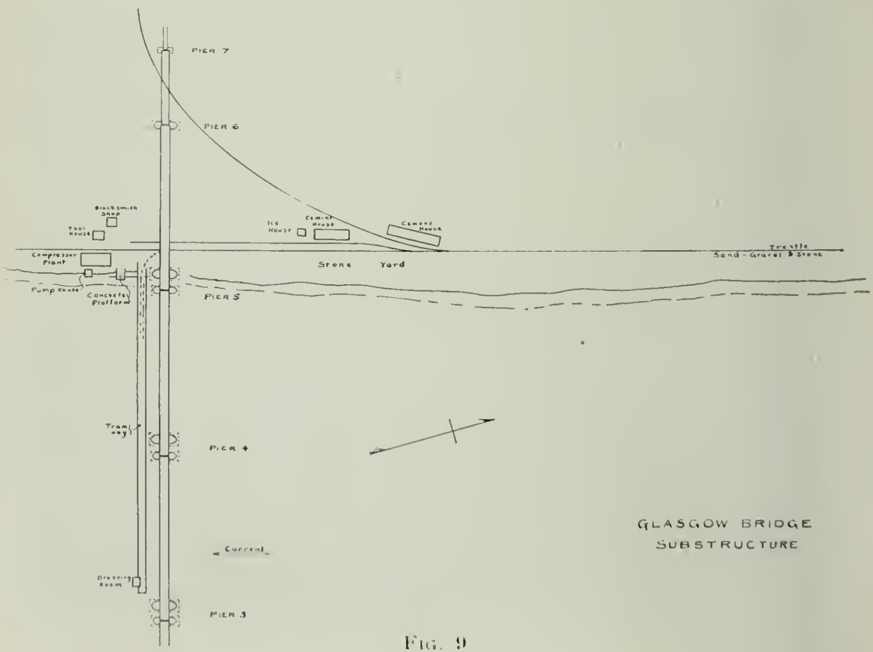


FIG. 9

plant used. The material was brought to the work on the track shown, crossing under the bridge between piers 6 and 7. Most of the sand, gravel and broken stone was unloaded from the cars on the trestle at the north end of the track. The cement was stored in the cement houses and the stone was unloaded and piled in the stone yard. In the stone yard were three derricks, which were all operated by one hoisting engine to the north of and in direct line with them.

The material did not come just as needed, so, owing to lack of trackage room and urgent demand from the transportation department for the release of cars, the railroad company found it necessary to unload the material as it arrived.

The contractors built a tramway extending from the west shore to pier 3, as shown in the sketch Fig. 9. This tramway carried the air pipes and the tracks for conveying materials to the piers. The location of the compressor plant is also shown in Fig. 9.

A track ran under the concrete platform. The materials were spread out in correct proportions and shoveled into a gravity concrete mixer, which discharged into a large iron bucket on a car on the track below. The car was then pushed over near the tramway and the bucket lifted by derrick to a car on the tramway track.

The gravity mixer gave very fair results. In freezing weather the water was heated, and the sand, stone and gravel thawed out by a steam jet.

A great deal of trouble was experienced with the frost cracking of the Bedford stone in cold weather, and in several cases slight delays in laying up the piers were caused by having to wait for stone to replace cracked ones. The stone that cracked from frost was doubtless poorly seasoned before the arrival of cold weather.

Piers 4 and 5 could not be finished before the removal of the deck spans over them, so in accordance with a clause in the specifications the contract was terminated when they had been built up nearly to the bottom chords of the trusses, the railway company completing them in 1900 after the removal of the old spans.

Fig. 2, already referred to, shows new pier 3 nearly completed, and also shows very plainly the relative sizes of the old and new piers.

Old pier 6 was in very good condition below the coping, so in adapting it to the new spans only the coping and belt course and one course below the belt were renewed.

Old pier 7, originally built of rather soft sandstone and on a comparatively shallow foundation, had been bound round with timbers and iron rods to hold it together. It was entirely removed and replaced by new pier 7, built of Bedford limestone on a pile and concrete foundation.

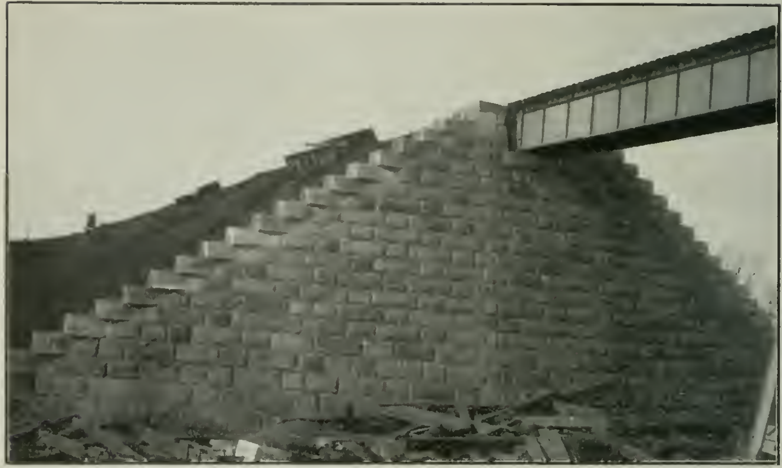


Fig. 10.

About 280 feet of the old iron west approach viaduct was filled and a large wing abutment (Fig. 10) over 40 feet high built to hold this fill. This abutment and the whole new west approach are also shown in Fig. 11. The abutment is founded on pile and concrete foundation and has Bedford stone facing with concrete backing. The unusual appearance of the step stones of the wing walls will be noted. The wing walls flare back at an angle of 13° 11′ with the front face except at the ends, where for a short distance the face is parallel to the central front face. This feature,

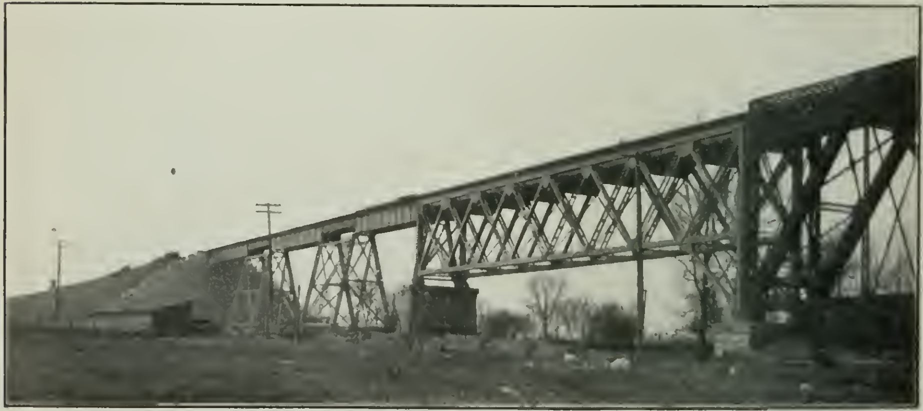


Fig. 11.

combined with the heavy batter of 3½″ per foot all over the face, causes the step stones to overlap.

The small pedestals for the trestle towers are of concrete with stone caps. The east approach piers and abutment were altered only enough to fit the new spans, and the old east approach pedestals were reinforced with concrete.

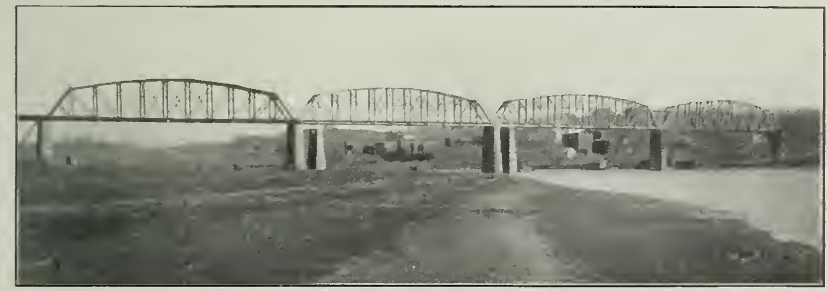


FIG 12

All of the work on the substructure done after the completion of the contract for piers 3, 4 and 5, was carried out by the railway company.

Fig. 12 shows the 4 channel spans of the new bridge, and the relative positions and sizes of old and new piers 3, 4 and 5.

DISCUSSION.

Gen. W. Sooy Smith The superstructure is really far the more important and interesting part of that bridge, as it was the first great steel bridge that was ever built—in fact, the first steel bridge of any importance built in the world. And I think it would be interesting to the Society to know something of the origin of the idea and its gradual growth, until it finally culminated in the construction of that superstructure.

I beg pardon of the Society for springing this thing, as it may not be pertinent to the subject under discussion, but perhaps I will never have any better opportunity to invite the attention of this Society to the facts which I will present.

In the year 1872 the convention of the American Society of Civil Engineers was held in this city. Most of us who had been grappling with the difficulties that attended iron bridge construction—that was my specialty in the beginning of my professional work—were anxious to devise some means for solving the problem of iron in the construction of iron bridges. The continuation of those difficulties had led us to consider some way out of it. The defects of iron were so marked that iron bridges had a hard struggle to compete with the best wooden bridges, and the progress made by them was very slow, particularly the tendency of the metal to crystallize under a heavy strain, and especially if attended by shock. The iron crystallized rapidly, and bridges that had been built of ample construction, as the character of the metal was supposed to be good, failed in a surprising way, and brought the bridges into disrepute and turned the attention of the best engineers in Europe, or in the world, to the matter of either correcting those defects in the iron or substituting some other material that would be free from those defects.

I had the honor to offer a resolution in that convention, just at the close of its final meeting, calling for the appointment of a committee of the Society, whose duty it should be to procure from the United States Government, if possible, an appropriation for the building of a first-class testing machine, and the appointment of a mixed board of engineers from the army, the navy and the civil engineers, to take that testing machine and to make a series of tests which would be comprehensive and exhaustive, to determine the quality of the various metals, not only of iron and steel, but all other materials used in the construction of bridges in this country. The resolution passed unanimously, and parliamentary usage made me the chairman of the committee.

There was associated with me Gen. McClellan, Gen. Barnard, Albert Fink and Jas. B. Eads. For three years we struggled with Congress, aided by the American Society of Civil Engineers, to secure the appropriation. The board was appointed in pursuance of the bill and an appropriation of $75,000 was made for the machine. There was a man created by the Almighty just in good time for the express purpose of making that machine. He invented a machine which is one of the most remarkable that ever existed on the face of the earth. It had an ultimate capacity of four hundred tons, both for compression and extension. With it the full strength of the machine could be developed to break or crush a specimen of iron or steel and the strain measured within a pound. The same machine broke a rod, for instance, developing the full strain, and could be applied to the breaking of a horse hair and measure the strain necessary to do that. Or it would crush a four inch cube of iron and then immediately crush an egg and measure accurately each stress required. That machine is still in existence, and notwithstanding years and years that it has been in use, developing a knowledge of our metals better than that possessed, probably, by any nation on the face of the earth—and even at this day it is a machine of the most extraordinary accuracy. It is at the Watertown arsenal and is subject to use by anybody who cares to do so.

Of course, this is a digression, but still it is pertinent to our subject, as you will see if you will follow it up, for the diminution of the weight of the superstructure influenced the design and the dimensions of the substructure. Shortly after the appointment of the Board I received a letter from an old gentleman at Burlington, Iowa, altogether unknown to fame, a gentleman by the name of A. T. Hay, and I wish you would all remember his name. He wrote me that for twelve years he had been engaged, in his quiet way, making tests upon iron and steel, and that he had succeeded in making various new alloys of iron and steel which showed most remarkable qualities. I sent a copy of the letter to the Board and asked their pleasure with regard to it, and they instructed me to invite Mr. Hay to a conference. This I did, and he came here, bringing some specimens with him. We examined those specimens together from two o'clock one afternoon until bright daylight the next morning, during which time I learned something and had my curiosity raised to a fever heat. He told me that for twelve years he had used an electrical furnace, as he termed it, for fusing ores, and that by means of it he had combined iron with each of the fourteen metalloids to form compounds in various proportions, and had tested the results very carefully.

Some of the specimens of the steel he had made showed an ultimate strength of one hundred thousand pounds to the square inch. I was so much interested that I went to Burlington to see his apparatus, which consisted of two concentric cylinders of sheet iron, the inner one lined with fire brick, built as any furnace should be. The inner cylinder was not over two and one-half feet in diameter and about four or five feet high. In the space between the inner and the outer cylinders he had coiled wires in positions he had learned by actual use were correct. Just how he used the current in aiding the fusion of the ores I could not discover at the time, nor at any time since; but in my presence he charged this furnace, put on the blast and heated the contents to redness without any appearance of fusion. "And now," he said, "I will show you the effect of electricity." He connected up his current and immediately the contents commenced streaming down like wax. After he made those alloys he hammered them into bars and had the bars tested in Chicago. He sent me a specimen, which I carefully tested, and for three months we were engaged in that kind of investigation of the qualities of the steel which he produced, and at the end of it I determined that one of those alloys out of the many specimens which he made was exactly the metal that we had been looking for for bridge building, and I so reported to Mr. Blackstone, the president of the Chicago & Alton, who had asked me to take charge of the Glasgow bridge as chief engineer.

In that connection I may state one other fact. Before reaching that conclusion for this particular bridge, I asked Mr. Blackstone to witness a test of some of the steel bars which Mr. Hay had sent me. We went to the American Bridge Works and broke them, and the last one, just one inch square, stood a test of 90,000 pounds. Mr. Blackstone said at once, "Build the bridge of that material." This test was made at a very low temperature, it was an exceedingly cold day, and the bar was broken in a cold room. During many of our tests at a low temperature the specimens were struck sharp blows with hammers.

When I concluded to build the bridge of steel and it became known, some of the best iron bridge builders in this country protested against it, and one of the very best of them, Mr. Pope, of the Detroit Bridge Company, said to me, "My God, Smith, you are not going to build a steel bridge, are you?" I said, "Certainly, why not?" He said, "The very first frosty morning that comes it will go into the 'drink.'" I said, "Very well, Pope; that only shows you are not up to date in steel." Notwithstanding the protests, it was determined to build it in steel, and it was built in steel. It remained in use for over 20 years without one single show of weakness anywhere, and during that 20 years the loads passing over it were almost doubled.

A little more information with regard to the superstructure and I am done. Instead of following the old rule of ascertaining the ultimate strength of the metal and then taking a certain factor, which was a factor of ignorance—a factor of safety it was called, but it was in reality a factor of ignorance—I always held and still hold that the elastic limit of that steel, tested as carefully as I have told you, ran up in this very kind of steel to 48,000 pounds to the square inch. Instead of adopting the factor of 5 to 6, taken from the ultimate strength, I chose to use one-third of the elastic limit, which gave 16,000 pounds to the square inch, and the parts of the bridge were proportioned by that rule. The maximum stress allowed at that time in iron bridges was 12,000 pounds per square inch. The weight of steel compared with that of iron for a truss of the same strength would therefore be as 12 is to 16, or 25 per cent less.

Now I must tell you one other little incident that may please you. At the time of the Centennial Exposition in Philadelphia, in 1876, Mr. Barlow, one of the most distinguished of the English engineers, was in this country. He and Mr. Hawkshaw had been sent over by England to attend the Exposition. I had the good fortune to make their acquaintance. I was then filled with the idea of building a steel bridge and so was Barlow, as I found in the course of my conversation with him. When we parted I said to him, "Mr. Barlow, you will have to look out; we will build a steel bridge in this country before you will in England." He said, "I guess not; we are far in advance of you in metallurgy and we are a richer people than you, and I will build a steel bridge before you will." So we parted. A few days after the Glasgow bridge was opened for traffic I received a letter from Barlow closing with the question, "How comes on your steel bridges?" I immediately went over to the telegraph office and wired him, "My steel bridge across the Missouri at Glasgow is coming on finely; the trains are now crossing it."

The quality of the steel developed by Hay at that time was just as high as it is now. He never was treated as he deserved to be, although he superintended, at the Joliet works, the making of several hundred tons of steel rails that proved remarkably good. The steel-makers stood aloof from Mr. Hay, astonished, although I believe they got all the information they could and applied it and still apply it. The steels now made are more the results of the discoveries of old man Hay than from any other source of information ever opened to the world. He was, as I think, the father of the modern structural steels.

Now, in point of fact that I built this bridge of steel, making it as I say 25 per cent lighter than iron, it looked like a spider's web away up at a height of 50 feet above water. I knew it would. It was therefore necessary, simply from an artistic point of view, to make the substructure as light and airy as considerations of safety and strength would permit.

There was another consideration influencing me to lighten the substructure as far as possible, and that was the matter of economy. That controlled me in using the amount of timber I did in the dock of the caissons. Timber was dirt cheap there, stone and concrete were expensive, and I could see no reason why it was not good engineering sense to put a very heavy deck on our caissons, laying the timber alternately, longitudinally and transversely, and drift-bolting heavily. It made a strong structure, more elastic than masonry; but during the construction of the pier the compression that timber got was about all it would take, even with the addition of the superstructure and its load, and that would be more than likely uniform. The timber was very uniform in character, the loads were equally distributed, and there was no reason why the compression should not be uniform, and so long as it was uniform, the timber being perpetually submerged, was cheap, strong and indestructible. I therefore used it, and would use it again under similar circumstances.

We were in a great hurry to build the Glasgow bridge and made accurate borings on the bridge line. I knew the location of the bed rock at every point to be occupied by the piers. Where No. 2 was situated the bed rock was bare of sand at high water; at low water there was some deposit of silt, and even there by the sinking of the structure the current would be accelerated sufficiently to scour the rocks bare. There I determined to sink an open crib, and then fill it with concrete at the bottom, pump it out and build my masonry. That we did, and if we had the cement available that we have to-day that would have made a first-rate structure. The imported Portlands were exorbitantly high, and the native cements were natural cements. Some of them were very good where slow setting was permissible, but the quick setting ones were very weak. The cement I used was very slow setting, and it was put down as carefully as possible; but it is not always a great success at any rate, no matter how carefully you manage it, and the concrete in the bottom of that pier No. 2 was not good. The bottom was not absolutely level, and where there were openings below the bottom of the crib work accessible to the water, this loose, crumbling concrete disappeared largely. That caused a partial failure of that pier. By adopting that method of construction I saved nearly a month in time. I had a limited equipment of compressors, and if I had had to sink another caisson by the pneumatic process it would have taken that much more time.

The other piers all went to the solid rock; this should have gone to the solid rock, but the bottom had not been laid perfectly bare. In every other instance it was. No. 4 longitudinal section, which you saw, showed the rock at the up-stream end—it was three feet lower at the upper end than at the down-stream end. We lowered the caisson to the rock at the down-stream end and channeled a little, cutting the edge of the caisson down into the rock and then built up masonry under the upper end, as the cross section showed under the timber part, and we filled the inside solid with concrete. The load coming upon the masonry and down through the inside of the caisson to the bottom, but not resting on the outer edge at all, the clearance at that place under the cutting edge was of no great consequence. It was built up of rubble to about the cutting edge, and that was deemed sufficient.

The bridge, for some time after its completion, appeared perfectly faultless. After a while cracks commenced to appear, not only in the pillars resting on the body of the masonry, but in the body of the masonry itself. The cause of those cracks is just as clear to my mind as anything can possibly be. I made a thorough examination of it and directed the repairs that were made. I know to my own satisfaction that it resulted simply from the imperfect character of the stone selected. We took the bulk of the stone from the new quarry that had been opened at Louisiana, that had not been tested—that is to say by actual use—and there was no means of determining absolutely whether it was durable stone or not when it was exposed to air. The selection of it would have been inexcusable but for the fact that in all other respects it did seem to be a promising stone. It was very hard and uniform in structure and composition and promised to be much better than Joliet or Lemont limestone. My observation since, not only on that bridge, but all the works built of Lemont limestone, is that it cracks on exposure if it has not been thoroughly dried and seasoned before exposure to frost. You can look at your docks along the river here and learn a lesson on that subject. Those cracks did not run as they would from a mere settlement, they ran in all sorts of directions. If a crack results from a settlement, you can generally trace the course of it and see what direction it ought to take and that it does take that direction. It was not so with those cracks, they ran out in all sorts of directions, and they simply resulted from the freezing and the thawing of the stone. We all know that limestone, if taken out and exposed to freezing before it is thoroughly seasoned, cracks to pieces. We avoided that as carefully as we could, but notwithstanding that, through years and years of service it behaved there as it behaves everywhere else.

Now, the reason of building those piers in columns instead of solid all the way up, has been a puzzle to a great many engineers. Those columns were supposed to be 7 feet square at the top; they were built of cut dimension stone all the way through, carefully laid in hydraulic cement. Strap iron was laid transversely and longitudinally in the beds to increase the strength of the bond. Now, the best calculations that you can make will convince you of the stability of those piers, and with the load they had their strength was ample to make them stand forever. Those piers, if they had been built of the same dimensions, with stone that was durable, would be as sound to-day as they were the day they were made. They cracked from the disintegration of the stone, not from vibration or strain. But, nevertheless, the fact is that they did crack, and that the bridge became insecure, and that it was necessary, wise and advisable to take them down.

As to the change from the foundation part of that substructure, except No. 4, to other foundations, I think it was entirely unnecessary. Those piers were just as good as the piers that have been built or any that can be built up to the water surface, at any rate, and they are of ample dimensions to have carried the new substructure. There may be other reasons which I don't know of why it might have been advisable to change the arrangement of the spans, but if new spans of ample strength to take care of the loads that are now passing over the bridge, and that may pass over hereafter, were put upon those foundations, they would be just as secure as they are to-day.

It is not necessary to go through with the struggles that we had. That bridge was built from start to finish in just one year. We had to contend with high water. The contractors who had the contract for building it made use of insecure false work under one of the spans, against my earnest protest, and the false work was carried away and the span was dropped into the stream. The contract dropped with it. The burden of the completion of the bridge fell upon my shoulders, as representing the Chicago & Alton Railroad, and we finished it ourselves under whip and spur. We had two or three of the spans in danger from the insecure false work when we took charge of it; but with the assistance of my superintendent, Mr. Thomas, who is present with us here to-night, we avoided that danger and saved both of the spans and completed our bridge. And I wish now and here to acknowledge the wonderful value of the services of the man who is now with us. It is not the engineer alone who builds the bridge, nor is it the superintendent alone; it devolves mainly upon those two men; but it is due, also, the "men behind the guns."

We had as good a force of men on the Glasgow bridge as I have ever seen, and we accomplished the work in the remarkably short time of one year, and for at least one hundred and fifty thousand dollars less than the cost of any other bridge on the Missouri River, built at that time or since.

That there were mistakes made, I am very free to acknowledge. What work is perfect? What man is perfect? And who are really the men who should command the confidence of mankind? The man who denies his imperfections; the man who pretends he knows everything, or the man who frankly acknowledges that he does not know it all, and that he has made and may make mistakes? If he can point to a clear record for successes, he is all the happier. But there are none of us who will go through fifty years of energetic work in civil engineering who cannot look back upon many, many grievous errors that we have committed.

Mr. Finley—Gentlemen, I think we are indebted to Gen. Smith for his very valuable historical data relative to the construction of this bridge, and especially the superstructure of it. Before the discussion closes there are some questions I wish to ask Gen. Smith concerning this metal, as I have had some experience with it myself.

Mr. Thomas—I think, from the very able description that the

General has given you of the bridge, it would be out of place for me to attempt to say anything of the very small part that I took in its construction. I was simply like the boy that drove the ass —I did what I was told.

There are some things, however, that occur to me. I care not what bridge I put up, you can never get me to consent to the use of natural cement for under water work. The Glasgow bridge, from the general description of it, reminds me somewhat of a horse I saw the other day on the street. It stood up splendid, looked fine, and I spoke to the man who owned it, and said to him: "Move your horse!" He says: "I can't, sir; his feet are a little sore." That was the trouble with the Glasgow bridge—its feet were a little sore.

In describing pier No. 2, which the General has done, he omitted one thing. It was built in crib form, caulked on the outside. If my memory serves me right, No. 2 was 28 feet wide and 50 feet long. I have not seen the drawing of that bridge for over twenty years. On the interior we built a large box of 6 x 12-inch pine, and caulked it. The purpose of this box was to enable us to go down near to the bottom in the interior, if we wished to, and also to give buoyancy in placing the crib. When the crib was put in, the Missouri River was at its worst. We moored the old pier in the stream, using two wire cables, 9 inches in circumference. The drift came down so heavily on the 4th of July that it parted our cables and carried No. 2 down stream. Gen. Smith came down and clapped his hands, and said, "Well done, boys;" but I did not notice him do anything with the ropes.

No. 2, after it settled, was worked just as the General described. Around this box we placed concrete, by a diver, after which we laid the cement concrete, and then stopped for three or four days before we tried to pump it out. As we could not do this on account of the leakage, it was concluded that we make a caisson out of this box, which we did. We put a roof on this and connected a shaft, improvised an air lock and conducted our air to it. I went into this improvised caisson myself, with one or two volunteers, and we forced the water out by boring holes in the bottom, and finally cut the bottom entirely out and went down and discovered where the trouble was. The difficulty was that the crib had settled upon a log, which threw it out of level. We removed that log, shut the water off entirely, using Portland cement in the dam.

I will follow this pier up and come to the year 1888. I have acted in the capacity of "wet nurse" to this bridge on a number of occasions. I have been down around those piers a number of times. In 1888, Mr. John P. Willard was in the employ of Sooy Smith & Co., and he put an annular around No. 2, brought that down to bed rock and pumped the water out. I was very much surprised one morning to get a wire from Mr. Booth, who was chief engineer of the Alton road at that time, requesting me to go down with Gen. Smith and himself to Glasgow to examine No. 2, and very much to my surprise he requested me to finish up this work for him by removing all soft material and taking out the old footing course and putting in a new one. I took every bit of the filling out from underneath, piece by piece, down to bed rock, cleaned out all around the whole pier, and after that was completed we filled in the trench with Portland cement concrete. The trouble seemed to be higher up with No. 2 than the point reached by myself, and I think the General has given you a very good solution, namely, in the disintegrated stone.

The Glasgow bridge was one of the first, if you remember; and when we put in the piers we had to stem the tide; we didn't have either anchors or piers to lash up to. I remember putting the first anchor crib out; it was 30x16x10, lashed up between two scows in the stream. The lashings were cut and down went the anchor, and so it goes all through. Gentlemen, I don't think it is proper for me to take any more of your time.

Mr. Finley—I was particularly interested in Gen. Smith's description of the material that went into the construction of the superstructure of that bridge. I have always understood that the old draw span of the Chicago & Northwestern R. R. at Kinzie street was the first steel bridge erected in this country. It was built of the same steel as the Glasgow bridge, so I have been told. I have always understood, while the Glasgow bridge was started before the Kinzie street bridge, the Kinzie street bridge was erected first.

Gen. Smith—I think it was erected before the Glasgow bridge was completed, and by the same manufacturers, but the Glasgow bridge was planned long before, and partly erected before the Kinzie street bridge. It was claimed that the same steel was used in it precisely. This I doubt. I have been told a number of times, when I have stated that the Glasgow bridge was the first steel bridge ever built, that I was mistaken—that there was some other steel bridge built over in Europe somewhere. If any of you know of any such instance I would be exceedingly obliged if you would give it to me. I do not believe that there ever was a bridge built of steel before the Glasgow bridge. The St. Louis bridge came as near as any. The tubes there are steel, but it is used in a different manner, in compression only. All the rest of the bridge is iron. In the Glasgow bridge every pound of it, every ounce of it was steel—the plates, the rods, the rivets, even the name plate. I was determined that there should not be any sort of question as to its being a steel bridge.

Mr. Thomas—I understand that there was a pair of girders built of steel in Sweden or Norway somewhere.

Mr. Finley—The order for the Kinzie street draw of the C. & N. W. R. R. was placed with the American Bridge Co. in the early fall of 1878, and the bridge was put in operation March 10, 1879, The erection of the Glasgow bridge was completed April 9, 1879, or just one month after the Kinzie street draw was put in operation. I was particularly struck with Gen. Smith's description of Hay steel and his remarks about wrought iron. I do not think that I ever had a bridge under my charge that gave me more trouble, from the character of the material in it, than the Kinzie street bridge. I had some tests made on that material after the old bridge was taken down, some physical and chemical tests. The chemical ones showed 0.24 per cent of carbon, 0.038 per cent silicon, 0.47 per cent manganese, 0.106 per cent phosphorus, 0.92 per cent sulphur. A plate taken from the upper chord had 0.42 per cent of carbon in it, and the average of the tests of the angles showed 74,500 pounds tensile strength per square inch, and of the plate 88,300 pounds tensile strength per square inch. The structure met with a number of accidents by being struck with boats, and when it was necessary to make repairs it required the utmost care not to do more damage in repairing it than there was originally. I understood at the time that the metal that Mr. Hay furnished was "a sponge"—I think he called it "sponge." I understood it was used in an ordinary Bessemer converter, and from my experience with it I would certainly claim that it was a rather unsatisfactory material.

Gen. Smith—I said that that metal was identical with the metal used in the Glasgow bridge, but I don't believe it was. I don't know that it was made under Mr. Hay's supervision. I do know that the tests of the metal that entered into the construction of the Glasgow bridge were most remarkable and thorough, every single piece of it tested by as able and as careful a man as I have ever known, Mr. Coolidge. I met him on the street the other day and he repeated what he told me before, and the report was that the uniformity was something wonderful.

We tested a great many parts of the metal, not those that went into use, and tested them to breaking, and we had a number of them that remained uniform throughout the length of five feet until reduced from a half to three-quarters of an inch in cross section—no reduction other than that at any one point. As I said, every single part of it was tested and tested carefully, and the quality of every single piece of it was found by such accurate tests to comply with the specifications which required that the ultimate strength should be 80,000 pounds; the elongation before fracture 10 per cent; greatest reduction at any point 10 per cent of the cross section. And the metal did fulfill that specification, and no metal that was not first-class would have done it. The conduct of the bridge itself showed throughout that the facts had justified all our best expectations with regard to it. There must have been some deception in the manufacture of the metal in the Kinzie street bridge. The presence of 0.106 per cent phosphorus and 0.92 per cent sulphur was hurtful.

Mr. Finley—I understood from Mr. Coolidge that it was the same as used in the Glasgow bridge.

Gen. Smith—He may have understood it so, but he did not make the steel. I suspect that steel was made clandestinely, by what was called Mr. Hay's process, to avoid the royalties that should have gone to him, and under such circumstances it is not strange that there should have been accidents.

Instead of recognizing the merit of it, and that that merit should go to his benefit, I know that it is used by a number of the best steel-makers in the world. The very formula used by Mr. Hay is very closely imitated in the best steel that is now made. Hay introduced, as a benefit, aluminum, nickel chromium, and other metals, relying very largely upon aluminum, and the best steel to-day is made with reliance upon the beneficial effects of such alloys. I ought to state that the carbon in the steel, according to our specifications, was about from 0.36 to 0.42 per cent. There was another evidence of the superior quality of the metal furnished by the span that fell when the false work was swept away: the span dropped 50 feet into the water, and was twisted into all sorts of shapes that you can imagine, and there was not one single case of short fracture to be discovered in the whole wreck.

Another thing, I am told that some parts of that metal were taken and made into tool steel.

CLOSURE BY H. P. BOARDMAN.

Relative to the remarks of General Smith and Mr. Finley concerning the steel of which the Glasgow bridge and the C. & N. W. Kinzie street bridge were made, I quote the following extract from a letter by W. B. Coolidge to August Ziesing. Referring to the Glasgow bridge he says: "The steel was Hay steel, made at the Edgar Thompson Works by Carnegie & Co. for Hussey, Howe & Co., who rolled the plates and angles. The eye bars were rolled in the Kloman mill, and the eye forged and the whole bar then annealed. Tests were made on each blow of steel. Tensile strength 80,000 pounds and upwards. The carbon required was 0.42 per cent. The same material was used in the Kinzie street bridge, but the carbon was about 0.30 per cent or under, and rivets 0.15 per cent. The records of tests were among the papers of the old American Bridge Co. at the works at 39th street. This is the extent of my knowledge and recollection of the matter."

In line with my remarks about the behavior of the intermediate posts when worked over, a number of the floor beams cracked while in use in the old bridge. In most every case the break was in a bottom flange angle near the end of the bottom cover plate, i. e., at a point of sudden reduction in flange section.

While the superstructure of this bridge was doubtless safe and economical for the loads it was designed to carry, it was probably not safe under the abuse of greatly increased loading, as bridges built today should be.

In this connection it should be noted that only the five 311 feet spans were steel, the three approach deck truss spans and the plate girder trestle approaches being of iron.

As to the stone used in the old piers, I have understood that all except the Joliet stone was from Grafton, at the mouth of the Illinois river. I believe the Grafton stone is very much like the Louisiana limestone, however. The Louisiana limestone has been used extensively for bridge masonry on the C. & A., and has generally given excellent satisfaction. It is far superior to the Joliet stone and costs more, being much harder and therefore more difficult to quarry and cut.

I think the cracking of the stone in the towers of the old piers can in part be attributed to the vibration consequent upon their slender design, since this disintegration developed so early in the life of the piers.

The stone in old piers 5 and 6 below the upper two courses, which have been renewed, is still in good condition, there being but few cracks in 5 and scarcely any in 6.

I think no one who has been familiar with the history and appearance of this bridge would venture to place a modern bridge superstructure on piers similar in design to old piers 1 to 4 inclusive, even if they were built of first-class granite, laid in the best of Portland cement mortar.

CXVI.

CONSTRUCTION OF CONCRETE MASONRY OF A CANAL LOCK ON THE EASTERN SECTION OF THE ILLINOIS & MISSISSIPPI CANAL.

By Jas. C. Long, M. W. S. E.

Read February 20, 1901.

The Illinois & Mississippi Canal is being constructed by the United States, and is under the direction of Major J. H. Willard, Corp of Engineers, U. S. Army, with headquarters at Chicago, and at the time of the construction of the locks was under Major W. L. Marshall, Corps of Engineers, U. S. Army, and all plans, methods of construction, directions, etc., emanated from his office, and were executed by me as U. S. Assistant Engineer, assisted by Mr. J. D. Truss, C. E., Mr. Chas. A. Browne, C. E., and Mr. S. L. Bayless, C. E., U. S. Inspectors, together with several junior engineers acting as sub-inspectors, the work while in progress being subjected to a rigid and close inspection.

Foundations.

These were executed by contract, and were on earth, with hardwood piles driven, as shown on plans of the work, sixteen feet into the soil, or until the blow of a hammer, one ton in weight, falling ten feet, produced a penetration at the last blow not exceeding one-half inch. The piles were then sawed off level at the proper grade, capped with ten inch by ten inch longitudinal pine timbers bolted thereto by iron drift bolts one inch in diameter and twenty-two inches in length, upon and across the longitudinal timbers, then were placed six inch by ten inch and ten inch by ten inch pine timbers bolted to the longitudinals, as show in the detail drawings, by iron drift bolts three-fourth inch in diameter and eighteen inches in length.

After leveling and ramming the earth at bottom of foundation, the spaces between and around the pile heads and timbers of the grillage were then filled with concrete, rammed in place and to the level of the top of the grillage timbers. The foundation was then planked over with two-inch pine plank, except the spaces under the lock walls, which were not planked over.

Four lines of sheet piles, driven eight feet below the bottom of the foundation and attached to wales and piles, were placed across the foundation of the lock, two lines near the head and two lines near the foot of the lock.

Broken stone and tile drains were placed beneath the foundation where required.

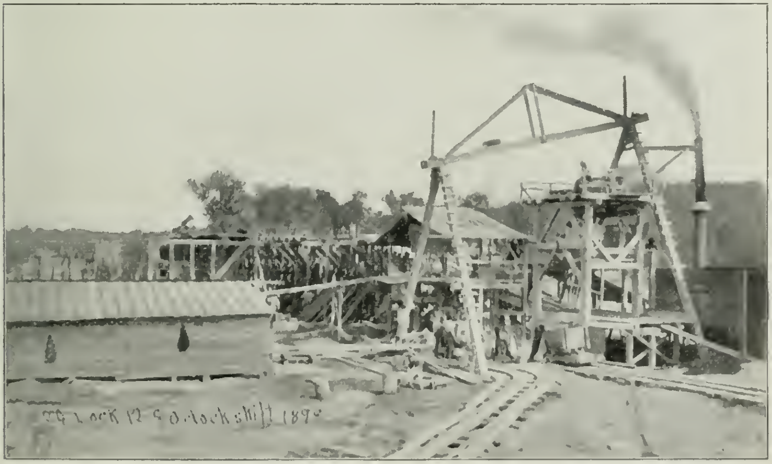
Concrete in Foundations.

The concrete in foundations was made of Utica natural cement, except just under the lower mitre sill, where Portland cement was used. It consisted of a mortar of one part cement, one part sand, and three parts broken stone or pebbles for natural cement; and one part cement, two and one-half parts sand, and five parts broken stone or pebbles for Portland cement. It was mixed by hand with sufficient water to cohere when rammed in place by thirty pound iron shod rammers, of not more than thirty square inches in area of face, in layers not exceeding four inches in thickness, and the bond between consecutive layers was secured by scratching the surfaces of the previously deposited layer.

When any section of concrete work was begun, it proceeded continuously to completion the same day from the bottom to the top of each course of the grillage timbers. When laid, the concrete was sheltered from the sun and kept moistened until set.

Lock Walls.

This work was done entirely by hired labor, and the concrete was mixed by machinery. Two four-foot cubical mixers were used, each being operated, with the hoist, by a portable engine. One of



Plant for Hoisting and Mixing Concrete.

these mixers was operated while the other was being set up at another lock site, so as to save time and keep the concrete mixing force constantly at work. Extra forms, enough for two and one-half locks, were also used for the same reason, and were set up in advance while the forms at one lock were being filled.

The walls were built in twenty-foot sections and progressed constantly, except on the Sabbath; three shifts of labor working eight hours each, were kept at work from the time a section was started until it was completed. The following distribution of labor was made in each shift of eight hours:

Overseer	1
Master laborers	2
Engine driver	1
Fireman	1
Laborers:	
Loading and delivering gravel and stone to the charging box	14
Opening and measuring cement	2
Operating water barrel	1
Mixing material for facing and coping	7
Operating and dumping agitator	2
Placing cars in position to receive mixed concrete	1
Operating hoist elevating cars from mixer to forms	1
On forms pushing and dumping cars	3
Spreading and ramming concrete	28
Shifting car tracks	2
Water boys	2
Total	68

Cement Tests.

A systematic testing of cement was made to make sure that the cement furnished maintained a uniform standard in respect to:

(1.) Soundness and change of volume. (2.) Time of setting. (3.) Fineness of grinding. (4.) Tensile strength.

The following rules were observed in the testing:

Natural Cement.

Natural cement is to be hydraulic, uniform in quality, of American manufacture, fresh, dry, finely ground, free from lumps, properly packed in good, sound barrels, or in strong, serviceable bags. Each barrel of cement to weigh not less than 265 pounds, net; bags, if used, will contain a fixed amount of cement, two or three bags to the barrel.

The cement must be slow setting, not beginning to set in less than thirty minutes, nor set hard in less than two hours, but must be set hard in ten hours. The tensile strength in pounds per square inch of briquettes, exposed twenty-four hours after mixing in air, and six or twenty-seven days in water, or as the case may be, shall be as follows:

	24 hours.	7 days.	28 days.
Neat cement......................	50	90	180
Mortar, 1 to 1 standard sand.......	—	75	180

The cement must be ground to such fineness that 90 per cent shall pass through a No. 50 sieve of 2,500 meshes per square inch, and 75 per cent through a No. 100 sieve of 10,000 meshes per square inch.

The cement must not check nor crack when made into thin cakes and exposed to air and water at ordinary temperature.

Portland Cement.

The cement must be of the best quality of hydraulic Portland, free from lumps, dry, finely ground, and securely packed in barrels, coopered of standard size, and lined with tarred paper so as to reasonably protect it from the air and moisture. Any cement damaged by water and caked to such an extent that the damage can be ascertained from the outside of the barrel will be rejected in toto and the barrel unopened. Barrels containing a large proportion of lumps will also be rejected. Each barrel of cement must weigh at least 370 pounds, net cement. Each barrel must be distinctly marked with its gross weight and with the brand of the maker.

The cement must be ground to such fineness that 99 per cent by weight shall pass through the No. 50 sieve in use in this office, and 87 per cent through the No. 100 sieve in use in this office.

The minimum tensile strength per square inch of briquettes exposed one day in air and 6 or 27 days in water, as the case may be, shall be as follows:

	7 days old.	28 days old.
Neat briquettes..........................	450 lbs.	540 lbs.
1 cement to 3 standard sand by weight.......	150 "	240 "

The cement must be slow setting, not beginning to set, as determined by the Vicat needle 1-12 inch diameter under ¼ pound pressure in 60 minutes. It shall not bear a weight of 1 pound on a wire of 1-24 inch diameter in 4 hours, but shall bear such weight in 12 hours.

The cement must not warp, check or crack, or show any other signs of disintegration or unsoundness under the following treatment: three thin pats of neat cement will be moulded on glass plates simultaneously and allowed to set in air (covered with a damp cloth to prevent surface drying) for 24 hours. One of these will be left in the air and another placed in water at ordinary temperature for an indefinite period; the third will be placed and allowed to remain in water at 212 degrees Fahrenheit for 24 hours or less.

Number of Tests.

A regular series of tests, as indicated herein, will be made on samples taken from not less than 10 per cent of the barrels. No other tests will be made unless specially ordered.

Change of Volume and Time of Setting.

These tests will be made simultaneously and by the "thin pat" test, as follows: place several ounces of dry cement on the mixing slab, and add enough pure water to make a heavy, viscous mortar. Work thoroughly with the trowel until smooth, transfer the mortar to small glass plates, spreading it out into flat cakes about 3 inches in diameter, ⅜ of an inch thick at the center and smoothed down very thin at the edges; set the plates aside where they will not dry too rapidly, and where not likely to freeze.

The time of setting is determined by the Vicat needle as described in the specifications.

The quantity of water used in making the test cakes has a great influence upon the time of setting, too much water greatly delaying it, and too little, not permitting complete hydration of the cement, gives misleading results. The proper amount is that which will make a stiff, plastic mortar and must be determined by experiment; it is approximately 24 per cent of the weight of the cement for Portland and 40 per cent for Utica.

At the end of 24 hours the cakes should be thoroughly hardened, and an inspection will show whether the cement has contracted or expanded appreciably during this period. An appreciable movement would cause the edges to crack and the cake to loosen its hold on the glass.

Three cakes should be made simultaneously from each sample, and all treated alike for 24 hours as above described. Then one cake should be left in the open air for an indefinite period and the others placed in water, one of them, in the case of Portland cement, being exposed to boiling water or suspended in the steam above boiling water for about 4 hours, the other being left in water at ordinary temperature. None of the cakes should show any indications of unsoundness under the treatment prescribed.

Fineness of Grinding.

A sample of 100 ounces made up from samples taken from 50 test barrels, or from each car load lot, should be screened through the No. 100 and the No. 50 sieve and the percentage retained by each sieve determined.

Ultimate Tensile Strength.

This is to be determined by breaking briquettes, in the Fairbanks machine, at ages of 7 and 28 days, the first 24 hours of this time being passed in air under a damp cloth and the remainder of the time in water. Four briquettes will be made from each test barrel. For the Utica cement (its character being well established on this work) all four briquettes will be made *neat* and all broken when 7 days old. For Portland cement two briquettes will be made neat and two with three parts of sand; one of each will be broken when 7 days old and the remaining two when 28 days old.

Mixing Mortar.

(1) For neat briquettes. Weigh out the necessary quantity of dry cement, about 5 ounces to the briquette, spread it in a ring on the slate mixing slab and pour the proper proportion of water into the center of the ring. Mix thoroughly with the trowel for 5 minutes, chopping up the lumps until the water is uniformly distributed and the mixture has the appearance and consistency of freshly dug earth.

(2) For sand briquettes. Weigh out the proper quantities of dry cement and sand and mix the two dry until they appear to the eye to be thoroughly mingled. To the dry mixture of cement and sand add the proper proportion of water, and then mix with a trowel for five minutes, turning and rubbing the mortar constantly until the water is well distributed and each grain of sand coated with cement paste.

Moulding the Briquettes.

After the mortar has been mixed as above described it should be deposited in the standard brass moulds (set on glass plates) in two or three layers, each layer being lightly packed with the one pound brass rammer designed in this office, the ramming surface having an area of about ¾ square inch. In packing the moulds the rammer should be allowed to fall by its own weight about one half of an inch. After the moulds are filled, both faces of the briquette should be pressed with the square trowel and smoothed down flush with the top of the mould.

Exposure of Briquettes.

As soon as the briquettes are moulded they should be set aside, still on glass plates, under a wet cloth, to protect them from too rapid drying, and left for 24 hours, the moulds being removed from the briquettes as soon as it can be done without injury to the latter. At the end of 24 hours' exposure under the wet cloth, the briquettes should be immersed on edge in a tray of fresh water deep enough to entirely cover them and left therein until they are to be tested for tensile strength. The water in the immersion trays should be slowly emptied and renewed by a running stream, or, if this be impracticable, it should be changed about twice a week.

Marking Briquettes.

Each sample of cement should be given a number of identification to be marked on the package from which it is taken, on the box containing such sample, and on each briquette made therefrom. This number and all information as to the date and nature of mixture, date of tests, etc., must be recorded in the daily note book.

Proportion of Water.

Experiments in the past indicate the best proportion of water by weight to be about as follows:

Portland Cement—
    Neat briquettes from 21 to 23 per cent of the cement.
    Mortar with 3 parts sand, from 10.5 to 12 per cent of ingredients.

Utica Cement—
    Neat briquettes from 30 to 33 per cent of the cement.
    Mortar with 1 part sand, from 17.5 to 20 per cent of ingredients.

Testing Machine.

The testing machine should be adjusted before each day's work of breaking briquettes; all moving parts and the inner face of clips must be cleaned and freed from dust and grit. The moulds must be cleaned after use and care taken not to bruise their edges in ramming.

The broken stone used was of sound and durable limestone, broken to pass through a 2-inch mesh, and the gravel used contained about 54 per cent of sand and 46 per cent of pebbles. This gravel was in its natural state, as obtained from a pit near the line of the canal, and it contained just a proper proportion of sand to fill the voids among the pebbles.

The following instructions for construction of concrete masonry were furnished me, and the lock walls were built accordingly:

Proportions and Mixing of Concrete.

Proportions and ingredients are measured by volume, and the number of cubic feet given below represent the quantities to be used for each charge of concrete put into the mixer.

Portland cement concrete shall in general consist of:

Portland cement................1 part = 5 cu. ft. = 5 sacks.
Gravel........................4 parts = 20 cu. ft.
Broken stone..................4 parts = 20 cu. ft.

For the wall supporting the upper gate and in the vicinity of the quoins the concrete shall consist of:

Portland cement........................ 6 cu. ft. = 6 sacks.
Gravel..............................20 cu. ft.
Broken stone..........................20 cu. ft.

Natural cement concrete shall consist of:

Natural cement ....2 parts = 8 cu. ft. = 4 sacks.
Gravel.......................5 parts = 20 cu. ft.
Broken stone..................5 parts = 20 cu. ft.

Facing material shall consist of, by volume:

1, Portland cement.
3, torpedo sand, passing No. 5 sieve.

The piles of gravel and broken stone shall be kept thoroughly sprinkled with water to clean surface of dust and to prevent absorption by the dry stone of the water used in mixing the concrete.

When delivered in bags, each bag of cement shall be emptied directly into the charging box, as the division of a barrel of cement into several bags diminishes the chances of injurious effect of a defective barrel, and hence the usual requirements of drawing charges from a mixture of five or more barrels may be dispensed with. When delivered in barrels this latter requirement will be observed.

All bags and sacks shall be carefully preserved for return to the dealers furnishing cement, in order to secure to the United States the rebate thereon, to be deducted from subsequent bills for cement.

The proper measures of ingredients shall be emptied into the charging box in the following order: 1st, gravel; 2d, cement; 3d, broken stone; 4th, water.

Enough water shall be added to make the concrete cohere after a thorough mixing. A greater degree of plasticity than that possessed by damp sand is required. The object is to have the consistency such that a thorough ramming will bring water to the surface. The mass of concrete should not quake on ramming; incipient quaking marks the limit, and any excess of water in one charge may be corrected by making the next charge a little dryer. The proper amount of water can be determined only by experience, and must be varied from time to time to suit the conditions of the weather and the ingredients. It is very important that Portland cement shall have sufficient water for its complete hydration. Natural cement requires less water for hydration than Portland.

The contents of the charging box shall be dumped immediately into the cubical mixer, which shall be revolved for not less than two minutes at a rate not exceeding nine revolutions per minute. The product is improved by long mixing, and all the time less than period required for initial set available between deliveries required at the forms should be utilized for extra turns to the mixer. The facing material shall be mixed by hand, and a very small gang will be able to keep the forms supplied, for a facing of uniform thickness of 2 inches, about 70 cubic yards only will be required for a lock, or about 3½ cubic yards to each section. A close watch must be kept of the quantity used, and the above limit must not be exceeded.

Depositing and Ramming Concrete.

Each lot shall be built in sections, averaging about 20 feet in length, making 10 sections to each wall. The planes of division between sections shall be at right angles to the axis of the lock, and are indicated on drawing furnished from this office.

Each section shall be a monolithic mass of concrete built continuously from the bottom to completion without horizontal joints. The sections shall be filled with horizontal layers about 6 inches thick, each layer to be deposited before the "initial" set of the previously deposited layer and then be well rammed in place.

The vertical planes of division between sections shall be made by transverse bulkheads built in the forms, and at each bulkhead a dovetail or recess shall be made for the interlocking of adjacent sections, the dovetails reaching from foundation to one foot below the coping of the sections.

Alternate sections shall be built first, then the bulkheads shall be removed and the remaining sections filled with concrete.

Before beginning a section, its foundation shall be swept clean with wire brooms and covered with a wet layer one inch thick of

1 to 1 cement mortar to make a close joint between the wall and the foundation.

The walls of the wooden forms shall be kept well wet during the progress of the concrete work to prevent their absorption of water from the newly placed concrete.

The lowest step or thickest part of the lock walls shall consist of not less than two feet of Portland cement concrete next to the face of the wall and a backing of natural cement concrete. All other walls or parts of walls shall be of Portland cement concrete.

The exposed faces shall consist of Portland cement and torpedo sand, 1 to 3. The thickness of facings shall not exceed 1 ½ inches nor be less than ¾ inch.

The facing and backing must go on simultaneously in the same horizontal layers. In order to gauge the thickness of the facing accurately, a light board or diaphragm of thin metal with convenient handles shall be set on edge parallel to and 1 ½ inches from the front wall of the forms. The facing material shall be deposited in the space between this board and the form. The concrete of the backing shall then be deposited and spread against the back of the board, which may then be withdrawn and the whole mass thoroughly rammed so as to bond the facing and backing by destroying the surface of demarcation between them; but no stone must be forced nearer to the front wall of the form than ¾ inch. No attempt shall be made to secure a definite surface between the Portland and natural cement concrete in the lowest step of the lock

Forms for Walls of Concrete Masonry Locks.

walls, but they shall be thoroughly bonded, blended and interlocked one into the other by long lap or splice joints in every layer deposited.

The top 6 inches of wall should have no broken stone — 1 part Portland cement, 4 parts gravel with large stones cast out. The top of coping for not more than 1 inch should be placed as soon as practicable upon this gravel concrete, mixed 2 parts cement and 3 parts torpedo sand, of consistency of mason's mortar, but quite wet, not stiff. It should be dumped and rapidly spread over the concrete and roughly finished. It should then be left to begin to stiffen and "shed its water;" but before its "initial set," and while still plastic, it should be finally finished smooth, well pressed and compacted into a firm, smooth coat and slightly crowned in the center.

View of Concrete Masonry Locks.

As soon as the setting is sufficient to stand it, the coping should be well sprinkled with water, and covered from air and the sun for several days, keeping it well wet until set hard.

The facing and coping shall show a smooth, dense surface without pits or irregularities. This is most likely to be secured by thorough and systematic ramming.

Concrete shall not be laid in water nor exposed to the action of water until thoroughly set. Concrete or mortar shall not be made when the temperature is lower than 35 degrees Fahrenheit in the shade, nor when rain is falling on it. All concrete work shall cease November 20, and not be resumed before April 1. Forms and moulds must be left in position for not less than four days after concrete is deposited. Freshly deposited concrete shall be protected from the direct rays of the sun and from wind by boards or tarpaulins, and as soon as a section of wall is completed the exposed coping must be covered with a thick layer of wet sand, and the whole mass of wall must be kept sprinkled until the concrete is thoroughly set.

Twenty-one locks were built as above. They are 170 feet long between gates, 35 feet wide in lock chamber, and have an average lift of 9½ feet. They contain, exclusive of foundations, an average of 2,567 cubic yards of concrete masonry to each lock, which cost $6.78 per cubic yard.

The average time consumed in placing this concrete masonry was 10 days for each lock. The longest time was 13 days and the shortest time was 8 days. The average amount of concrete placed per day was 256.7 cubic yards, and the largest average per day on any one lock was 320 cubic yards.

DISCUSSION.

The Secretary—The question is asked by one of our members: In dumping the material down into the forms, was there any use made of rakes or such appliances to distribute the stuff uniformly before commencing the ramming?

Major Long—Yes; spread in layers. The specifications stated it should be spread in layers and rammed.

The Secretary—Did you discover any difficulty in assimilating the Portland cement concrete and that made from natural cement, when the two kinds of concrete were used at the bottom of the walls?

Major Long—None at all.

The Secretary—Can you tell us anything further in regard to the temperature effects and such matters; in regard to shrinking or otherwise, when the work was completed?

Major Long—There may be some very slight cracks; frequently one may find a small crack about the middle of each section.

The Secretary—As though in shrinking it had pulled away and parted in the middle?

Major Long—In the middle, and some places where there was an angle, as in the gate recesses, there would be a little crack.

The Secretary—As I understood from your paper, you built one section and there was a cross bulkhead at the end of the section. You built, for instance, the first, third and fifth, and so on, sections, and then went back and built the second, fourth, and so on, sections. Was that the fact?

Major Long—Yes; the bulkheads were removed before the alternate sections were built; there was a simple dovetailing at the joints, but there was nothing else between the sections.

The Secretary—Mr. Wheeler, in his reports on the construction of the "Poe lock," mentions the advantage from the use of limestone chips from the dressing of the stones for the lock construction. All the stones were dressed by stone planers at the lock site, and this gave a great amount of small chips, which he said he used in the concrete and obtained a smooth surface without the use of a facing coat that you describe as being put on the concrete walls. Did you try anything in that line?

Major Long—No, I did not.

The Secretary—What was your method of determining the portions of the mass of your work, as 1 of cement, 1 of sand and 3 of gravel?

Major Long—By bulk measurement.

The Secretary—Did you have any way of determining that in the gravel that you found in the bank, that the voids of the pebbles were filled with the sand that was in the same bank? Did you use any measuring box filled with the bank gravel and then filled it up with water to determine the voids?

Major Long—No, we did not; just simply by inspection.

Mr. Boardman—I would like to ask Major Long if he has seen any indications of the mortar facing on the locks separating from the concrete and sounding hollow when tapped.

Major Long—Only in one place, on Lock No. 2, I think, when you stamp your foot on it it sounds hollow; that is the only place. We had trouble in the surface cracks in the first lock, but after a while we found that after the concrete set a while the surface would throw off water, then a refinishing with a trowel would obviate surface cracks.

Mr. Boardman—Was there any opening up of the vertical joints formed between the different sections by the bulkheads?

Major Long—No, sir.

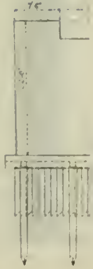
Mr. Boardman—As I understand it, the openings formed in the middle of the sections.

Major Long—Just that crack; with that exception it is all practically solid.

Mr. Miller—I would like to ask Major Long about the brands of cement used?

Major Long—We used two brands of imported cement—the Alsen and the Star Stettin; and of the American cements we used the Atlas, the Alpha, the Saylor's and the Empire.

Mr. Shnable—Since the utility of a mortar face has been discussed, I might add that an experiment was made at Joliet in



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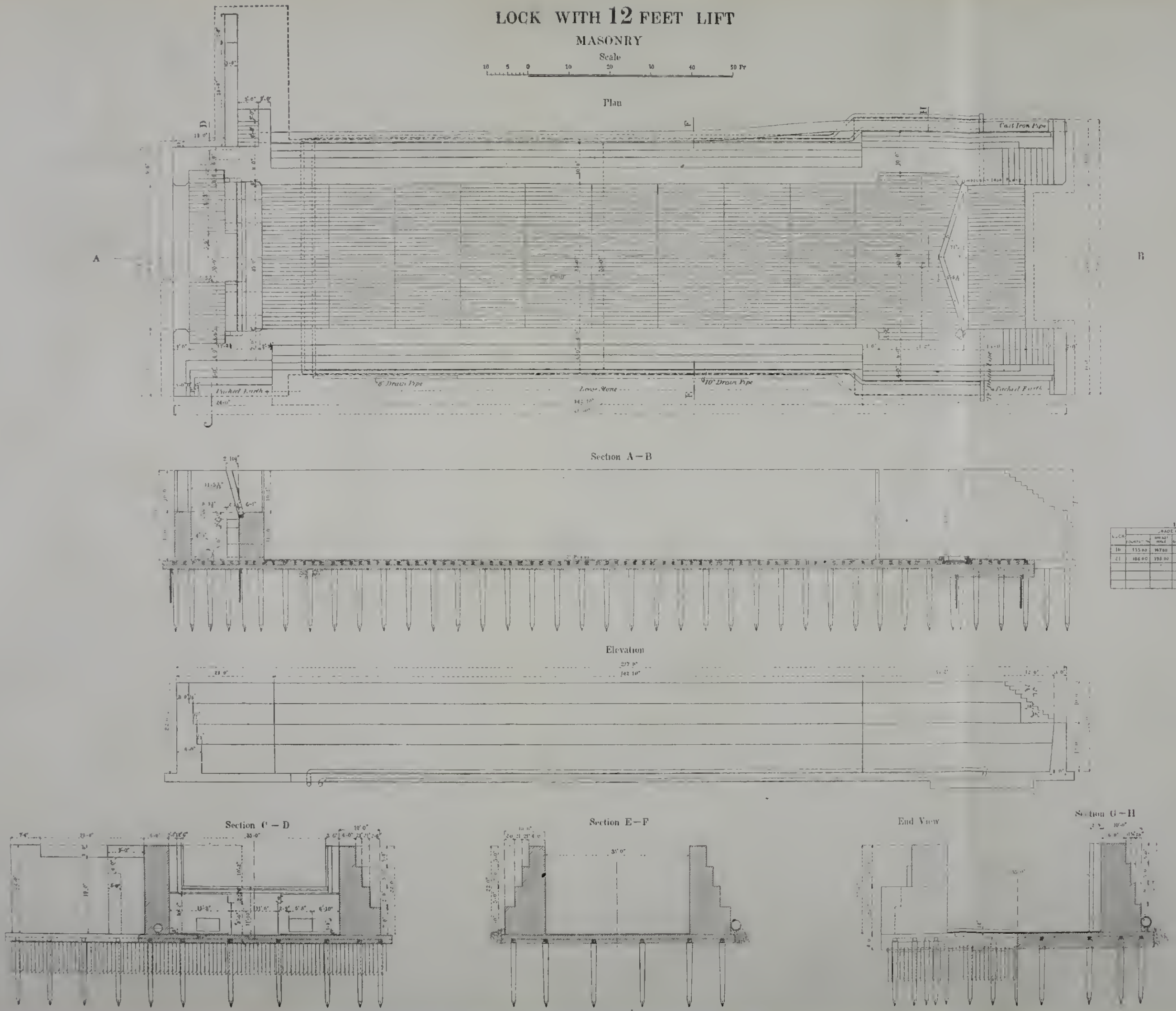
Long—Concrete Locks.

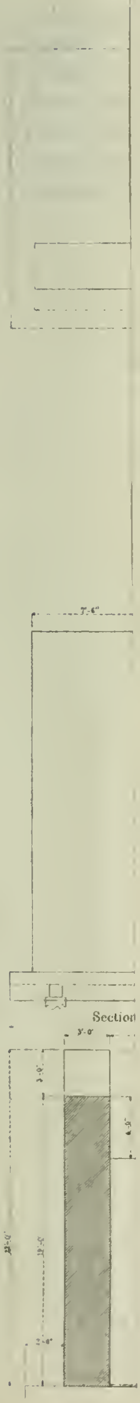
LOCK WITH 12 FEET LIFT

MASONRY



USED FOR

Lock	Grade of top of					Remarks
	Foundation	Breast wall	Upper gate walls	Lower gate walls	Lock walls	
16	133.00	167.00	166.533	134.00	157.[illegible]	42" C.I. Pipe
21	186.00	198.00	197.033	197.00	208.[illegible]	48" " "


7'-6"
Sectio
3'-0"
3'-0"

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Long—Concrete Locks

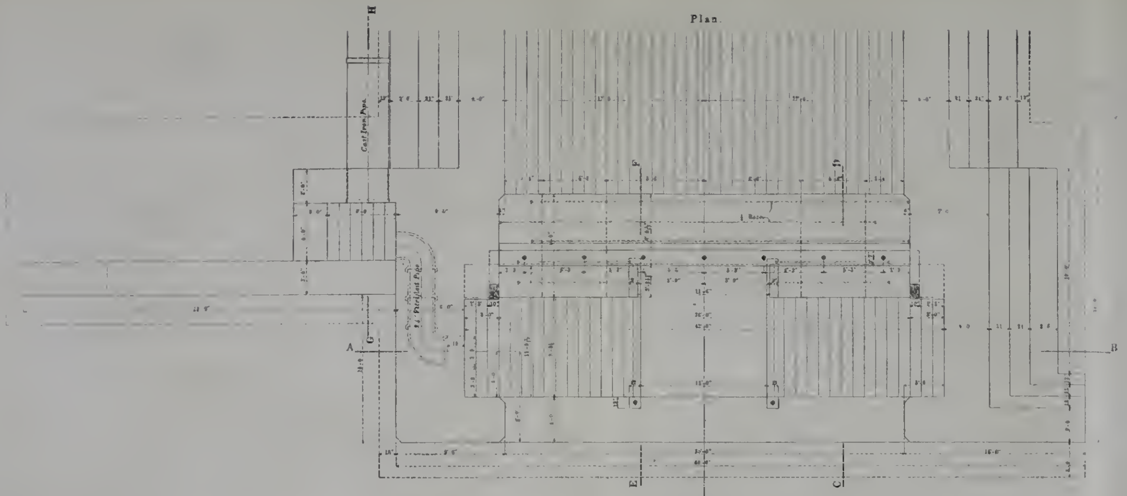
LOCK WITH 12 FEET LIFT.

AUTOMATIC UPPER GATE.

DETAILS OF

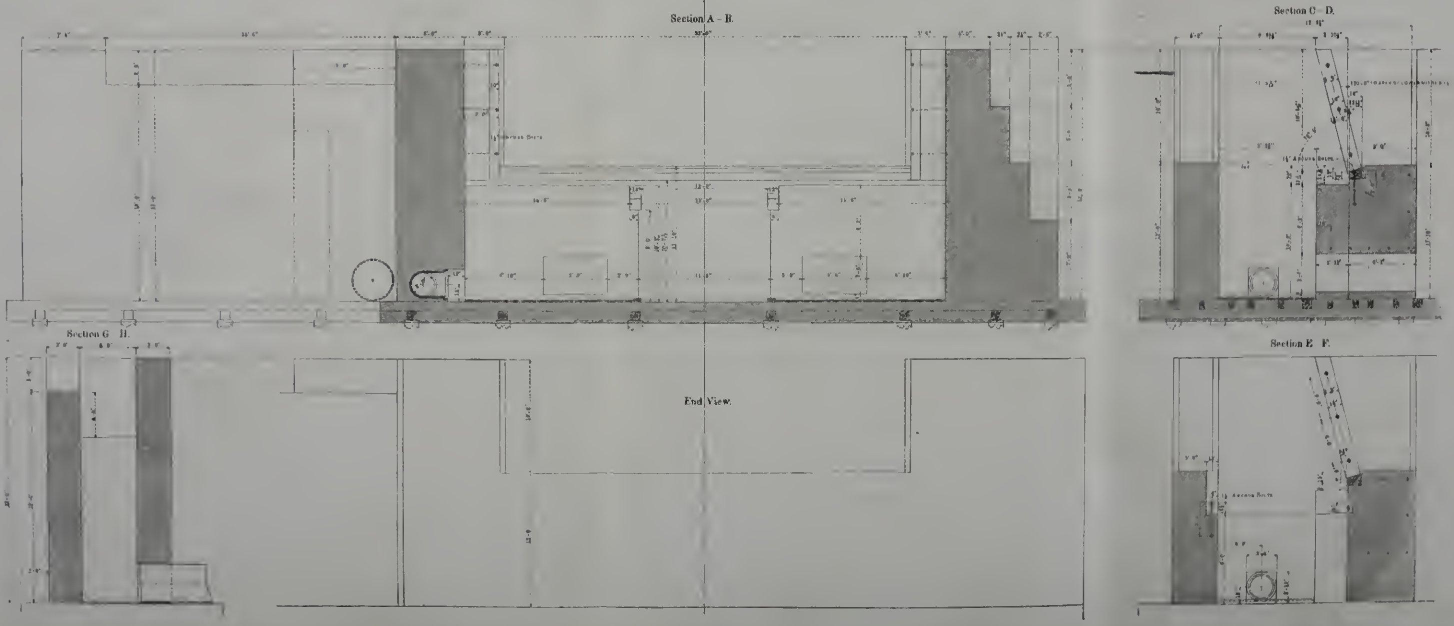
UPPER PORTION OF LOCK.

Scale
0 5 10 15 20



USED FOR

LOCK	GRADE OF FOUNDATION	TOP OF UPPER GATE WALL	BREAST WALL	LOCK WALL	UPPER WATER LEVEL	REMARKS
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]" CAST IRON PIPE CULVERT
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48 " " " "



erecting pillars three feet square at the Economy Light and Power plant. The superintendent of the concrete work did not believe in a mortar face and built one of the pillars with a skin face. Later, during the installation of the heavy machinery and iron work, these pillars were more or less bruised by bumping. The pillar with the skin face appeared to have the hardest surface and withstood the shocks the best.

CXVII.

DISCUSSION OF PAPER XCVI.—"RESERVOIRS AND THE CONTROL OF THE LOWER MISSISSIPPI."

By Maj. C. McD. Townsend, U. S. Engineers, Rock Island, Ill.

In a paper on "Reservoirs and the Control of the Lower Mississippi," by James A. Seddon, M. W. S. E., there is suggested the improvement of the lower Mississippi river by means of reservoirs situated in the St. Francis basin. The author proposes to reduce flood heights at Cairo to 42 feet, drawing off the water at stages over 32 feet, storing the water thus abstracted from the river and returning it at Helena in such a manner that the low water discharge below Helena will never be less than 300,000 cubic feet per second. He demonstrates the practicability of such a project, and claims that it will not only diminish flood heights but reduce caving, and increase the low water navigable channel of the river some 15 feet.

A simple examination of the hydrographs of the Mississippi river shows that without levees in the St. Francis basin, a flood of 52 feet at Cairo has never been able to raise the floods at Helena to heights exceeding 48 feet, and a study of these hydrographs indicates that if by cross dams the water that flows into the St. Francis basin during floods could be retained there, the greatest floods at Cairo would not produce at Helena elevations of the water surface exceeding 45 feet on the gauge. Such results would be very valuable and are worthy of careful investigation. The sole question is: "Would the reservoir construction be cheaper than an improved levee system?"

But the influence of these reservoirs on caving and on the depths over bars during low water is not self-evident, and merits a more extended discussion than it receives in the paper. Discharge observations were taken at Helena in 1882, under the direction of the Mississippi River Commission, and the mean discharge curve for the year and the corresponding curve of mean velocities is shown in Plate I. The reduction of floods at Cairo to a 42 foot stage will necessitate the withdrawal from the river at extreme flood stages of about 500,000 cubic feet per second, about 1,200,000 cubic feet per second flowing down the main stream. From the discharge curve it will be seen that at Helena a discharge of 1,200,000 cubic feet per second has a mean velocity of 5.4 feet, while at extreme flood stages the mean velocity of discharge is about 7 feet. A discharge at Helena of 300,000 cubic feet per second corresponds to a gauge height of 17 feet and has a mean velocity of between 3.5 and 4.0 feet—about that of the flood discharge of the upper Mississippi at Winona, Minn. Such a velocity on the upper river has been capable of moving heavy gravel and will very actively erode the light sands of the lower river. A river with a mean velocity of 4 feet per second will have at some portion of its cross-section a maximum velocity of over 6 feet, and where the maximum current is close to a bank of sand, rapid caving will result.

The writer published in his report to the Mississippi River Commission for 1893, the results of observations taken at Louisiana Bend for the purpose of determining the locus of the thread of maximum velocity in the river cross-section at various stages. The results are shown graphically in Plate II. These observations were taken 5 feet below the water surface, and show that at low stages the maximum current in Louisiana Bend was about 200 feet from the concave side of the bend. When the gauge read 1.4 feet this maximum was 2.5 feet per second. As the river rose there was a rapid increase in the velocity 200 feet from the caving bank, until when the gauge read 26.7 feet it attained a maximum of 9.35 feet per second. As the river still further rose, while the mean velocity of the entire section increased, the locus of maximum velocity moved further out into the stream, and at 200 feet from the caving bank the velocity dimished. At a stage of 40.5 feet, corresponding to a discharge of about 1,300,000 cubic feet per second, the maximum velocity was over 1,200 feet from the concave bank, and at a distance of 200 feet was zero. At a stage of 17 feet on the gauge, the velocity 200 feet from the caving bank was about 6.5 feet.

The effect of limiting the river to ranges between 17 and 32 feet would have resulted in producing, during the entire year along the caving bank of this bend, velocities varying from 6.5 to 9.3 feet per second, and eliminating the periods when the velocity varied between 0 and 6.5 feet.

While it can be assumed that in bends the stage of maximum caving will rarely be the same, but will vary with their radii of curvature, the relation to the bend above, and other elements in the regimen of a river, it can also be predicated that the maximum caving of a concave bank will rarely occur during times of extreme flood. Water, like electricity, follows lines of least resistance. During low water, these lines follow the pools in the bends with abrupt crossings between them. The slope over the bars is greater than around the bends, but the friction is so much greater in the shoal water on the bar that the river currents "hug the bank," as pilots express it. As the river rises, not only does its velocity increase, but the friction over the bars diminishes much more rapidly than in the pools, and a stage occurs when the steeper slope across the end of the bar offers a line of less resistance than the longer path around the bend. The maximum current then follows the line of least resistance, and the velocity along the concave bank diminishes.

There are, however, other elements than velocity of discharge that cause caving. It has been observed that if water flows in a straight regular channel, so that the filaments of water tend to move in straight lines, a greater velocity is necessary to cause erosion than if the currents first impinge on one bank and then on the other. In the first case, a cross-section of the channel would show a horizontal water surface; in the second case, the water would be found piled up on the bank on which it impinges, and the water surface of its cross-section would show a slope toward the opposite bank, increasing with the sharpness of the bend and the velocity of the current. This slope is frequently much greater than the slope down the river in the bend, and tends to give a spiral motion to the water down the concave bank and obliquely across, which action is very conducive to caving and the production of a long bar extending down from the opposite bank diagonally across the river. This action should attain its maximum at a stage somewhat lower than that at which the thread of maximum velocity starts to leave the concave side of the bend.

Omitting from discussion evaporation and percolation, the water which would be stored in the St. Francis reservoirs would lose only such energy as would be necessary to force it through the outlet near Cairo, and should possess approximately as much force when it arrives at Helena through the reservoirs as when moving down the river on the crest of a flood. At a flood stage, however, it flows at a mean velocity exceeding 6 feet per second, while if released from the reservoir at a 17 foot stage the mean velocity of discharge would be less than 4 feet. As this can take place when the slope is the same, this difference of velocity measures a loss of energy which is absorbed by friction on the river bed, i.e., erosion.

In the formula for velocity, $v = c\sqrt{r s}$, whether applied to a pipe, a sewer, or a river channel, it is found that as the area of cross-section increases, c increases, i.e., a less percentage of force as measured by the slope is expended in overcoming friction.

The only filaments of water that produce friction or erosion on the bed of the river are those in contact with it. The great mass of flowing water is wasted, as far as the moving of material is concerned. If the cross-section of the channel were a semi-circle, the wetted perimeter would vary as the radius, and the area of the section as the square of the radius. The greater the section, the greater the percentage of water that is not employed in bank erosion. During floods, a large percentage of the water escapes over the banks and has no influence whatever on the channel. A less amount of the force producing erosion would be dissipated with reservoirs than when the river is not under control.

It is submitted that the author's contention that the reservoir system would reduce caving to a small fraction of its present proportions, even if it did not entirely remove it, is not proven. It is the opinion of the writer that such a reservoir system would very markedly increase caving in bends, with a consequent increase of deposit in the crossings below. It would widen the river, and, perhaps, deepen it in the pools, but would have little effect on the bars.

In a sewer or wooden flume, an increase in the discharge produces an increase in the depths of water flowing, which can be determined mathematically, but in a river whose channel has been formed in material it has deposited, and as readily moves, this is not so. As the discharge increases, the velocity increases, and a greater amount of this sedimentary material is removed from the banks and deposited on the bars below. When the river rises, the elevation of the bars increases; when it falls, the bars cut out. The rate of rise and fall of the sand bar does not, however, correspond with the rate of rise and fall of the water surface: so that better navigation exists at high stages of a river than when the water is low. But the poorest navigation is not found ordinarily at extreme low water. As the discharge diminishes, the water falls considerably before an appreciable cutting out of the bars occurs; and if the fall is rapid, shoal water may occur at a comparatively high stage. But a permanent increase in low water discharge causes a corresponding permanent increase in bar heights. There are submitted profiles of the Mississippi River channel, at localities where navigation was notoriously bad before the improvement of the river was undertaken, derived from the survey of the upper river in 1879, and of Lake Providence Reach by the Mississippi River Commission.

Below St. Paul the extreme low water discharge of the river is about 2,000 cubic feet per second; below the mouth of the Chippewa about twice as great; below Quincy about ten times, and at Lake Providence Reach over fifty times that at St. Paul. Yet at the stages at which the observations were taken, the distance from the extreme low water lines to the crests of bars is approximately the same. As the discharge increases the pools deepen and the distance between bars increases, but the depth on bars remains constant. But, as before stated, the height of the crest of the bar is a factor of the stage of the river. As the water falls, there is a tendency to cut a channel through it. This is particularly true of the light sand of Lake Providence Reach. Nevertheless, the reports of the Chief of Engineers show that at Lake Providence Reach, navigable channels having a depth of but 4.5 feet have existed; below Quincy, depths of 30 inches; at St. Paul, depths of 2 feet. Increasing the low water discharge ten times has increased the available low water navigation but 6 inches; increasing it 50 times has increased it but 2.5 feet. If the same law obtains, a permanent increase of the low water discharge to 300,000 cubic feet per second would not give navigable depths during low water which would justify the expenditure necessary to obtain it. The writer recalls a case on the Lower Mississippi where he found but 6 feet over a bar at an 18-foot stage; when the river had fallen to low water, there was a navigable channel 12 feet deep at this same locality.

While the idea that "the ills of the river in the main lie in the variations of its flow, and to equalize the flow is the first if not the only step required to making the best of the river" may be a fundamental one, it is only true for the portions of rivers with so gentle a slope or stable banks that there is no appreciable erosion.

Wherever the Mississippi River has a gentle slope, slight current and permanent banks, a good navigable channel is found, and an increase in the low water discharge is accompanied by an increased depth over the crossings, as well as in the pools, as illustrated in Plates IV and V; but wherever slopes exist that create currents of sufficient velocity to cause excessive bank erosion, navigation is difficult during low stages of the river.

In Plate VI is shown the low water slope from Chicago to the Gulf of Mexico via the Illinois and Mississippi rivers, and the mean stages from Chicago to the Gulf of St. Lawrence via the Lakes and St. Lawrence River. There is an essential difference between the lake control of the St. Lawrence system and the proposed control of the Mississippi River by reservoirs in the St. Francis Basin. In the St. Lawrence system the lakes occupy the bed of the river, and concentrate the fall at Niagara and the rapids of the St. Lawrence. Where the fall is thus concentrated, the river has a rocky bed little subject to erosion, and resembles a large stone sewer. Along the route from Chicago to the Gulf of Mexico the fall is more uniformly distributed, and would be unaffected by the proposed reservoirs in the St. Francis Basin. On

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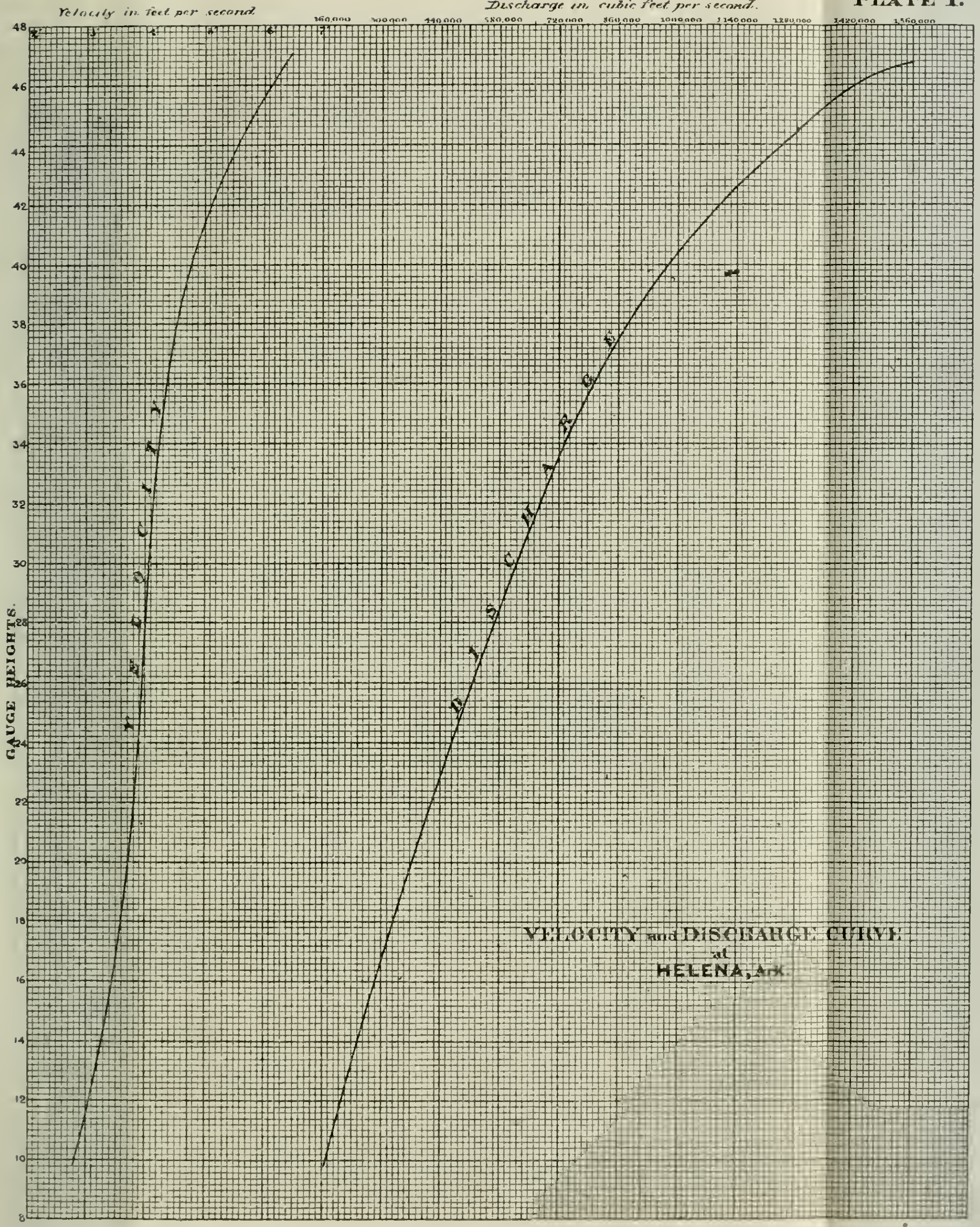
Mississippi River.

PLATE 1.



VELOCITY and DISCHARGE CURVE
at
HELENA, Ark.

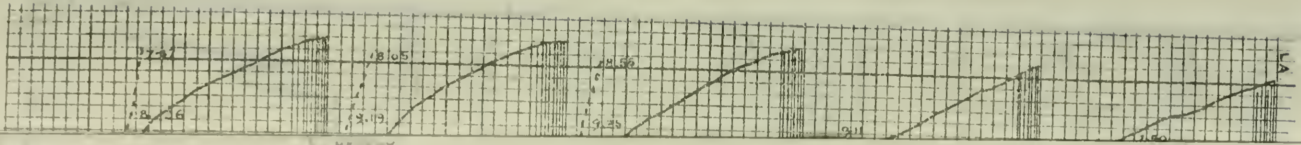
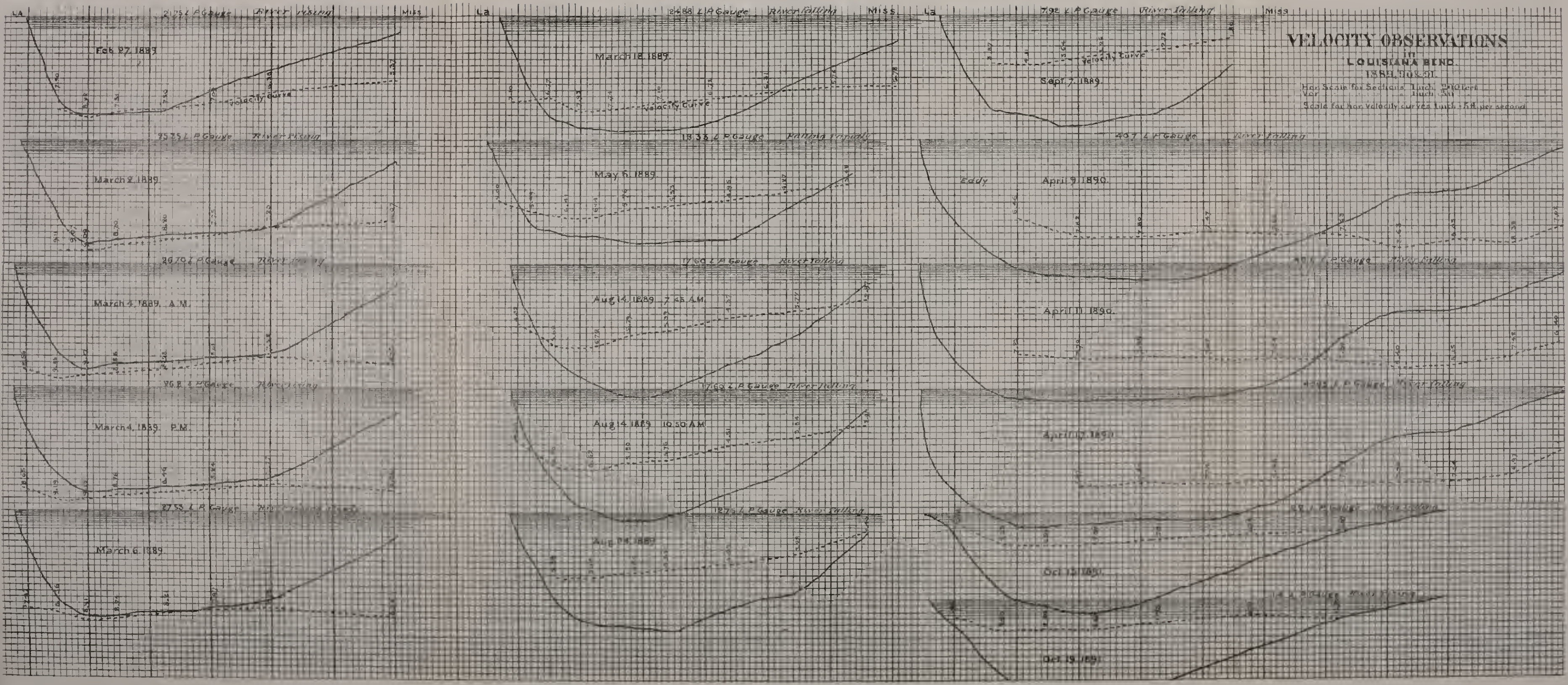
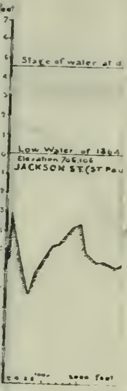
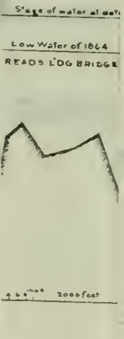

17.47
18.36
18.05
19.19
18.56
19.35
21
19.50
LA.

PLATE 2.


VELOCITY OBSERVATIONS
in
LOUISIANA BEND.
1889, 90 & 91.
Hor. Scale for Sections 1 inch 200 feet
Ver. 1 inch 5 ft
Scale for hor. velocity curves 1 inch = 5 ft. per second
La
Miss
Feb 27 1889
March 18 1889
Sept 7 1889
March 2 1889
May 6 1889
April 9 1890
Eddy
March 4 1889 A.M.
Aug 14 1889 7.45 A.M.
April 11 1890
March 4 1889 P.M.
Aug 14 1889 10.50 A.M.
April 12 1890
March 6 1889
Aug 29 1889
Oct 13 1890
Oct 19 1891
Velocity Curve
River rising
River falling
Falling rapidly
L.P. Gauge


feet
7
6
5
4
3
2
1
0
1
2
3
Stage of water at d
Low Water of 1864
Elevation 706.106
JACKSON ST. (ST Pau
1000 2000 feet


Stage of water at dat
Low Water of 1864
READS L'DG BRIDGE
1000 2000 feet

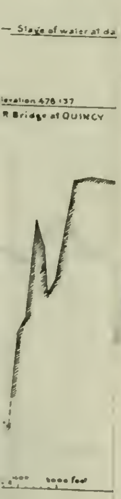

Stage of water at da
levation 478.137
R Bridge at QUINCY
1000 2000 feet

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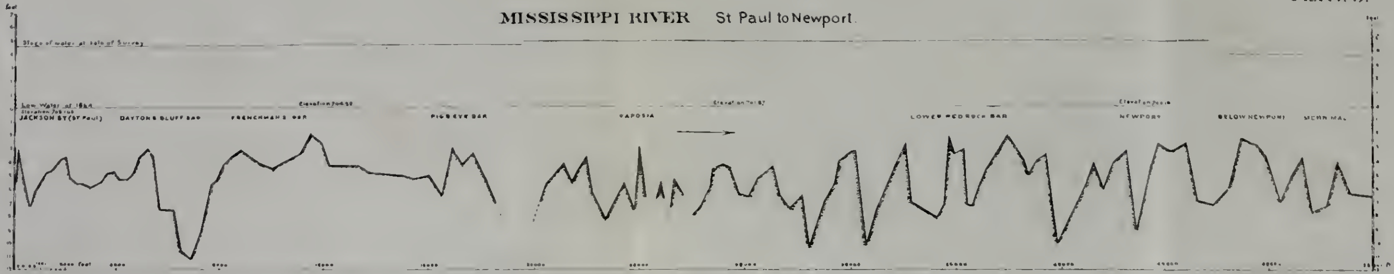
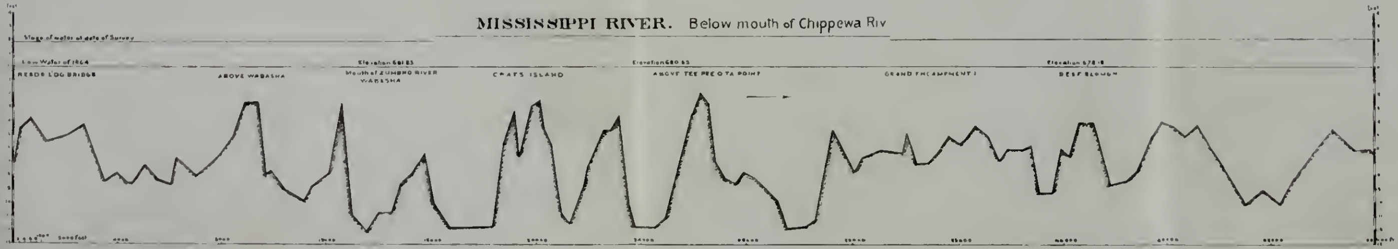
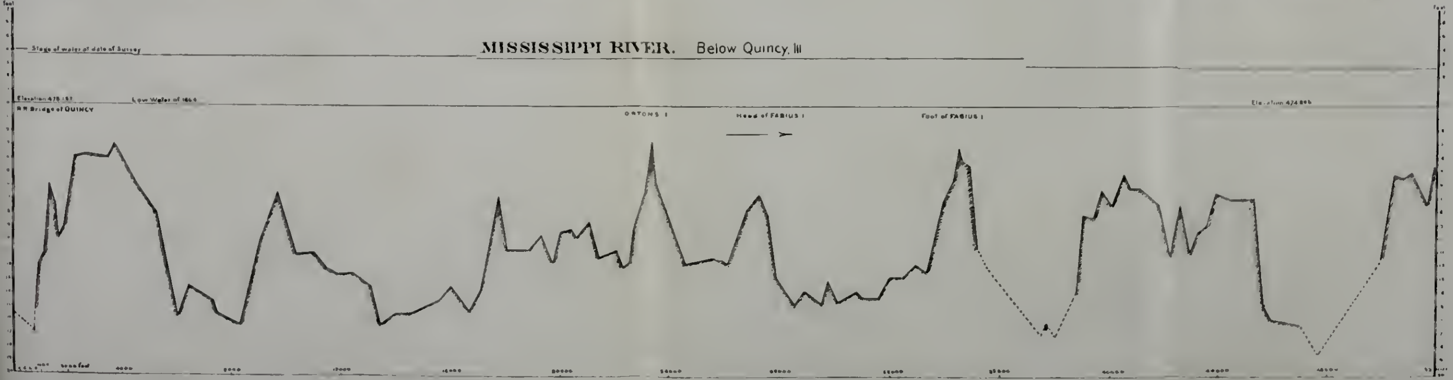
PLATE 3.


MISSISSIPPI RIVER St Paul to Newport.


MISSISSIPPI RIVER. Below mouth of Chippewa Riv


MISSISSIPPI RIVER. Below Quincy, Ill

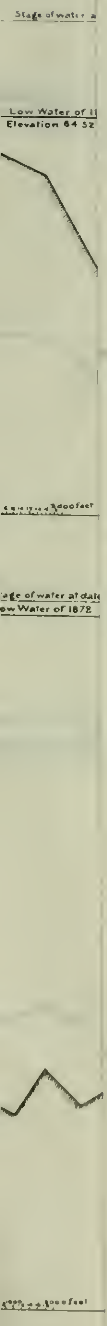

Stage of water a
Low Water of 1
Elevation 64 52
3000 feet
tage of water at dat
ow Water of 1872
1000 feet

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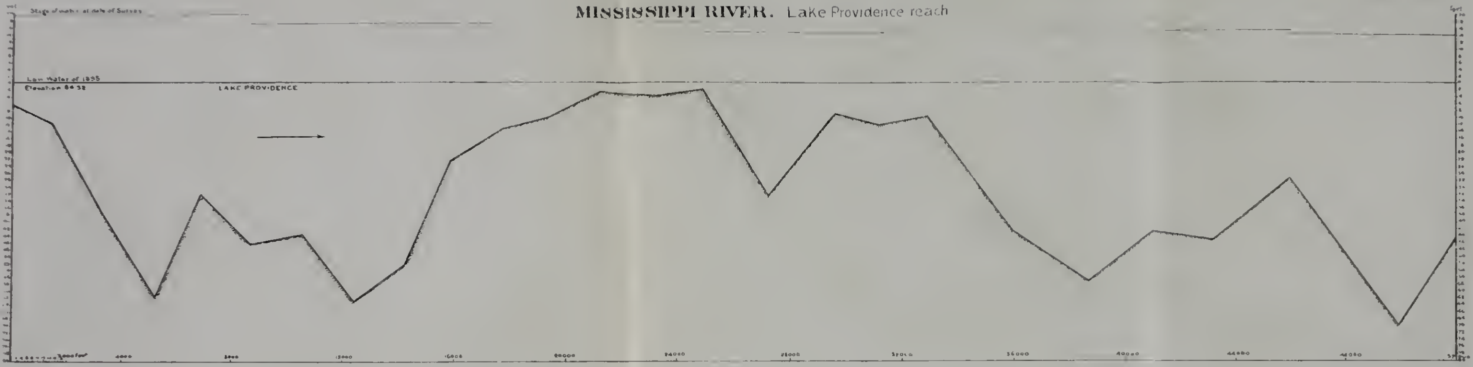
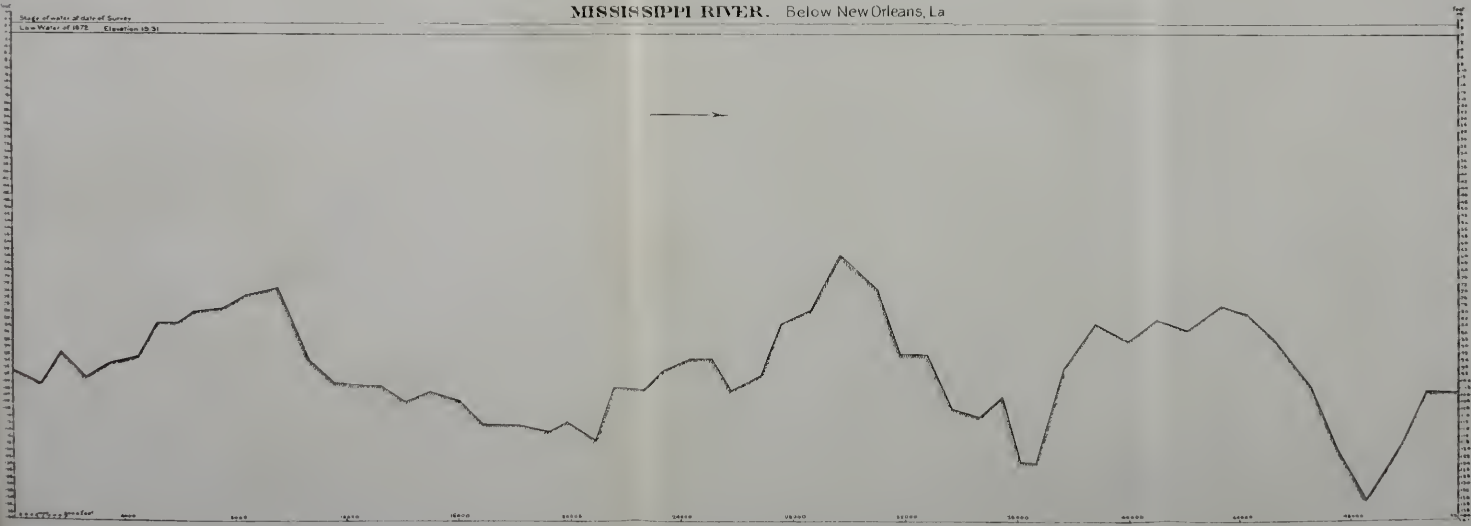
PLATE 4.

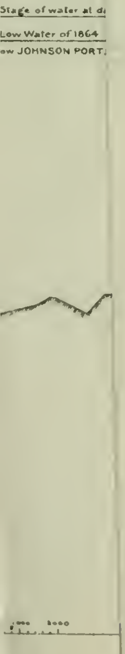
MISSISSIPPI RIVER. Lake Providence reach



MISSISSIPPI RIVER. Below New Orleans, La



Stage of water a
vation 685 69
TRENTON
2000


Stage of water at d
Low Water of 1864
ow JOHNSON PORT
1000
2000

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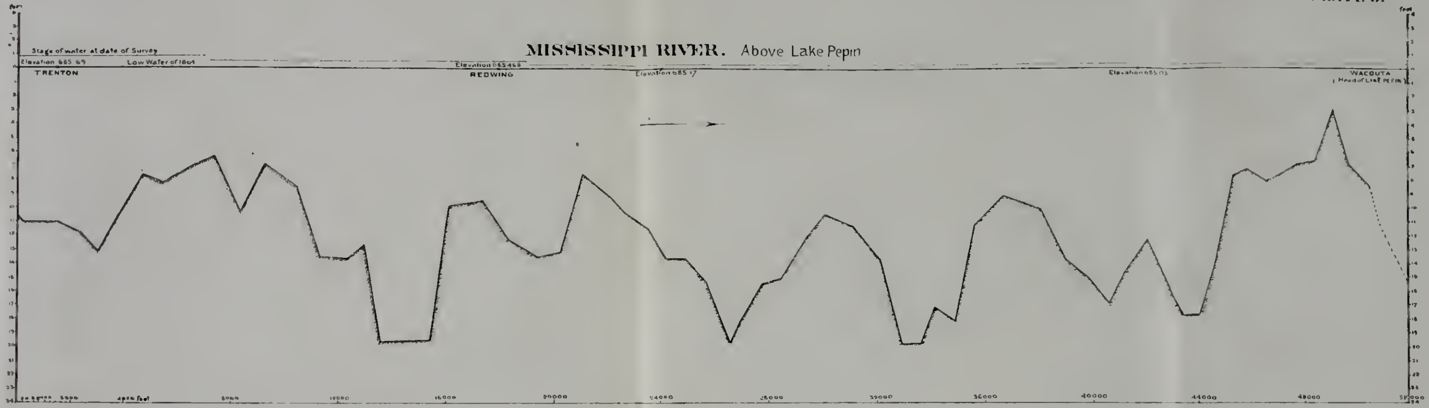
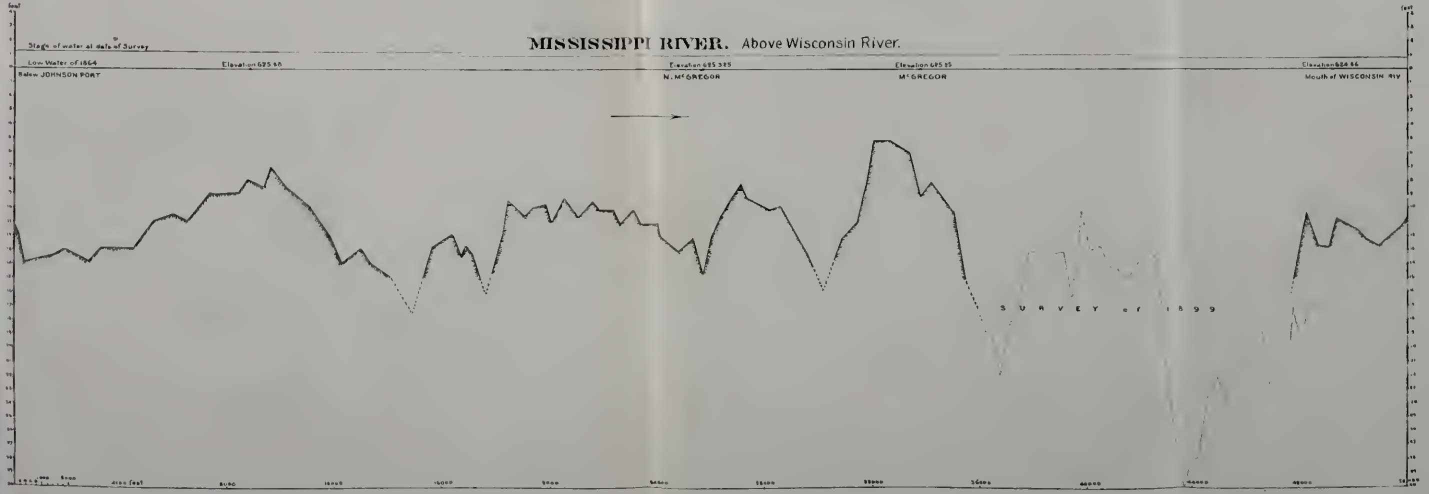
Mississippi River

PLATE 5.



MISSISSIPPI RIVER. Above Lake Pepin



MISSISSIPPI RIVER. Above Wisconsin River.

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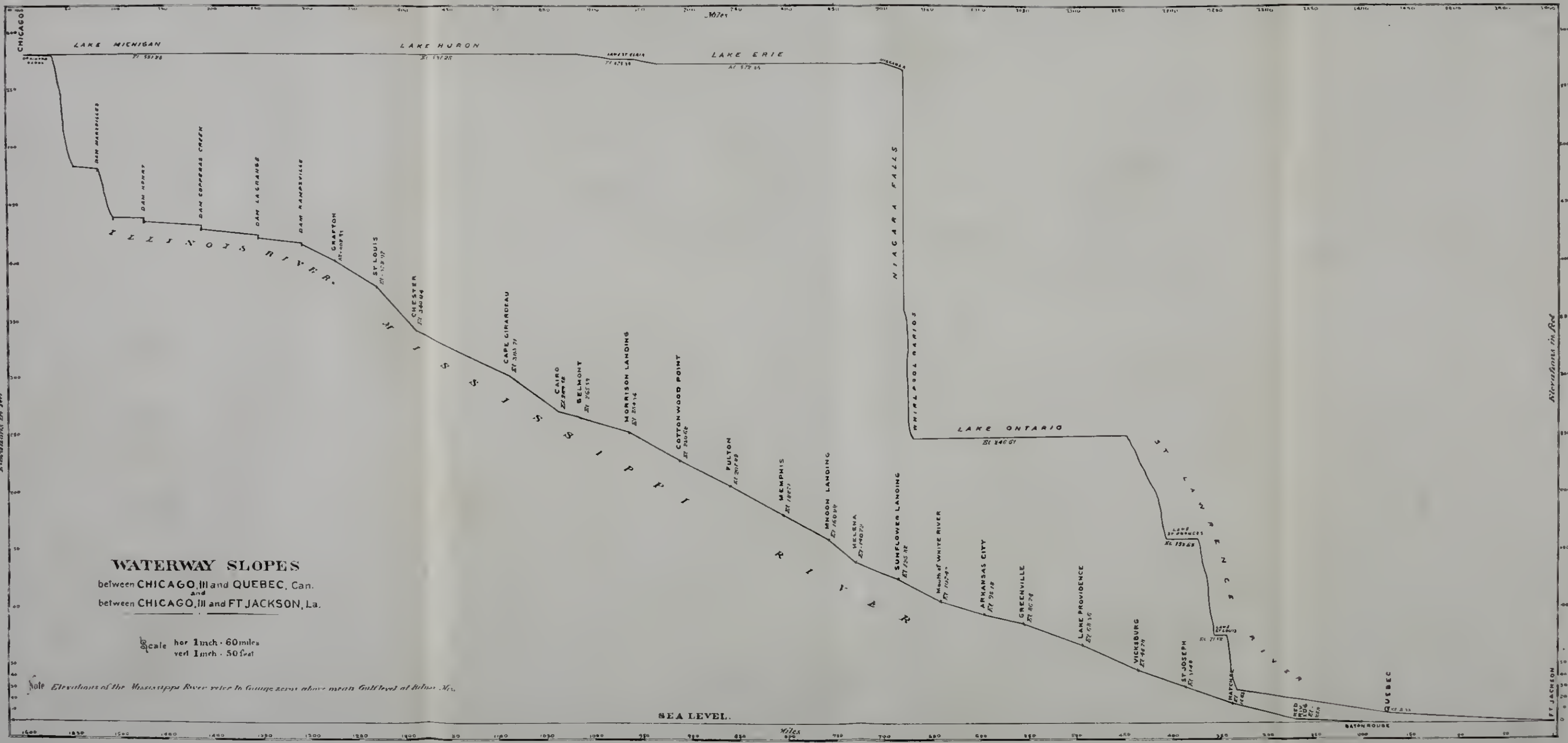
PLATE 6.



WATERWAY SLOPES
between CHICAGO, Ill and QUEBEC, Can.
and
between CHICAGO, Ill and FT JACKSON, La.

Scale hor 1 inch · 60 miles
vert 1 inch · 50 feet

Note Elevations of the Mississippi River refer to Gauge zeros above mean Gulf level at Biloxi Miss.

the Illinois or Mississippi river, the bed is very generally composed of material deposited from the river itself, and therefore capable of being affected by moderate currents. From Utica to Grafton, the Illinois River has so gentle a slope that a large addition can be made to the low water discharge without producing velocities sufficient to cause erosion; but on the Lower Mississippi caving occurs even at the lowest stages, and to reproduce the conditions existing on the St. Lawrence would necessitate either the construction of dams at Helena to the elevation of Niagara Falls, and at Natchez to the elevation of Lake Ontario, or the placing of some material on the banks which will enable them to resist the flow of water. Increased discharge will then be accompanied by increased depths.

CLOSURE BY JAMES A. SEDDON.

The main purpose of the writer in his original paper was to show in general the effects of reservoirs on the flood and low water stages of a river; with the effect on the lower Mississippi of the St. Francis system in particular. In this it was necessary to put the great mass of data bearing on the subject in such a form that the whole thing would simply speak for itself. With alternative projects of river improvement, a fixed policy in the Government work on the Mississippi, the Mississippi River Commission in charge of this work determined to ignore the reservoir project. A report of a Senate Committee against it, and the local organization of all the levee districts down the river looking with scant favor on a line of river improvement that promised to make their work no longer necessary, it was not easy to bring the matter out in such a form that it would call for a reconsideration of this reservoir project on its merits. The writer is, therefore, gratified to find that Major Townsend recognizes the essential accuracy of this showing, and its important bearing on the subject of flood protection for the Mississippi Valley. The writer, however, must take issue here with the conclusion that the sole question is, "Would the reservoir construction be cheaper than an improved levee system?" unless this is intended to cover much more than the cost of the reservoir system on the one hand, and that of completing the levee system on the other. There is also to be considered, first, the relative cost of maintaining the two systems when completed, and, second, the degree of safety which the respective methods of flood protection promise the valley.

Considering the cost of maintaining the levee system, in the original paper it was assumed that the average life of the levee is not much over forty years; though, of course, no such rate of renewals is as yet found in a system that has practically all been located within the last fifteen years. New levees are not put where they will cave into the river in a few years; but the time comes, nevertheless, when the bank erosion reaches them. Taking $70,000,000 as the cost of the yardage in the completed levee system, this 2½ per cent a year is $1,750,000 alone, and $2,000,000 as a total for yearly maintenance is altogether less than many of the river engineers have estimated it. On the other hand, the cross-levees in the St. Francis reservoir system are not built upon the caving banks of a river, and will have relatively little cost of maintenance. The earth put into them is put in to stay forever; while they offer a line of work that may be built upon from generation to generation as a more and more perfect control of the river is wanted.

Considering the question of safety, in the great floods the crevasses in the front levee lines is even now a serious matter to the people some 25 feet below the water level in the river and 20 miles from a bluff; and the crevasse is more likely to occur, and promises to be more destructive when it does occur, as the level of the extreme high water is raised to the limits of the completed levee system. It is to this risk that the lives and properties of all are exposed behind the 1,500 miles of levees from Cairo to the Gulf. On the other hand, the reservoirs are not completely filled until the flood in the river has practically passed. In a perfectly symmetrical flood the time of its crest or highest water would be the time when the reservoirs are just half filled, and not until the flood had gone by would the full head of water against the cross levees in the reservoir system be reached. Even if a crevasse should occur then in one of these cross levees, the water could be run out into the river without injury, while there would be no destruction to life and property in its track. A somewhat larger levee is contemplated here for the longer periods that it is to hold the water, but it has standing water against it in place of the flow on the face of the front levees, is sealed more and more with the sediment deposited by the yearly fillings, and has altogether some 200 miles to take chances with, against the 1,500 miles in the front levee system.

In the matter of reduced erosion and increased depth that would follow the construction of this reservoir system, the writer would like to remove Major Townsend's doubts on the subject, but he can not cover so large a field in this discussion, and can only briefly outline some of the leading points in it. In an official report to the Missouri River Commission, some two years ago, the writer presented fully the methods in which these phenomena of erosion and bar building could be followed and the questions finally determined. Later he gave an outline of this system of "River Hydraulics" in a paper to the American Society of Civil Engineers, and the methods are now open to the criticism and tests of the whole engineering profession. With this, the officers in charge of these works are in a position to remove their own doubts when they want to, and intrusted as they are, with the large annual expenditures for the improvement of these rivers, it is to be hoped that they have at least taken some steps to do so.

But while accurate estimates can not now be given of this reduced rate of erosion and increased depth resulting from these reservoirs, still Major Townsend stands absolutely alone among river engineers, so far as the writer knows, in the direction in which he takes these changes, and the estimates that he puts on them. As an instance of an opposite view, and at the same time a very comprehensive analysis of the phenomena of these rivers, the writer gives the following from a paper by L. E. Cooley:

THE DYNAMICS OF ALLUVIAL STREAMS.

"An alluvial stream is simply Nature's device for letting water down hill without wholesale removal of the material in which the channel is fashioned. There is a certain methodical adjustment by which the channel is adapted to variations in flow, from flood to low water, and to grade—exhibited in width and variations thereof and in alternations of depth and the fluctuations in bed or bars.

"In streams of fairly steady flow, the channel is found tolerably uniform and fixed in regimen, with grade fairly adjusted to volume flowing, or such as is due to a moderate or non-erosive velocity. Alluvial streams may also be stable, with channel narrow and deep and tolerably uniform, with a velocity sufficient to maintain the channel and a grade due thereto. The conditions of stability for narrow and deep channels, tolerably uniform in prisms, *are uniform volume and low grade*, provided the grade is not too low to give the necessary velocity in an economical prism.

Most alluvial streams, for the greater portion of their courses, have grades in excess of flood requirements, and the result is a *wide and variable bed by which flood velocities are restrained*, so that the material is not removed by wholesale faster than it is contributed. If the channel most economical for flow, narrow, uniform and deep, persisted, flood velocities would be so great as to sluice away all the deposits of the valley in a brief period, and the valley would be denuded.

In addition to this general adjustment of channel prism, there is a general variation by which high water erects barriers to rapid flow, which are torn down on the falling stage, or in the readjustment of the low water regimen, and this is characteristic of alluvial streams on steep slopes, as in the Missouri and Middle Mississippi; finally, the slope may be so steep as to compel a broad, flat bed, in which low water finds no adjustment, as in the Platte River in Nebraska.

"All these phenomena are mainly functional, are not accidental; hence, the many failures to accomplish results on the theory that Nature had been guilty of an accident which only required man's intelligence to correct.

"*The river prism is largely the carving of the high water period;* the low water fashions its course through the barriers. In the adjustment or transition, is the period of bad navigation. This general law has many limitations.

"It follows, therefore, that any proper scheme of improvement, so far as practicable, avoids disturbing the high water regimen. To generally narrow the river would increase its velocity and ultimately lower its bed, or exaggerate its vertical irregularities, and both these results have attended the rectification of some European rivers. There would seem to be a limit to the results attainable by rectification alone, excessive rectification defeating its purpose, unless the river is so circumstanced as to readily part with its slope in excess of that required by the rectified width and deeper channel—in any event, a process of indefinite time in long rivers.

"Moderate rectification may not radically disturb high water conditions and may accomplish much in correcting what appear to be abnormal developments.

Beyond this, equalization of flow by increasing the low water volume, seems to be the more conservative factor. Conjointly, the two satisfy the known conditions of uniformity in channels.

'' Increase in low water volume does not directly disturb the regimen of the pool, as the prism there is largely in excess; in fact, the place of constraint (this takes with it the slope) is shifted from the pool to the bar early in the falling stage, and the pool becomes a place of deposit for the bar erosion which is soon marked below mid-stage.

'' So far as low water conditions approach those of steady flow, the tendency is to carve and maintain a bar channel or *prism directly in proportion to the volume;* that is, the channel will develop until the velocity is reduced to the non-erosive limit, which may be assumed as tolerably constant for a given stream. It follows, therefore, that the mean bar depth between the fixed limits, *will be increased directly as the volume*, and the channel depth even more The same limiting or ruling velocity at nearly every tidal entrance, has been observed, modified only by the character of the litoral drift and by the forces that drive it.

'' If, with the natural volume, the low water channels are constantly maintained by the works of improvement, much more persistent should be the deeper *channels produced by increased low water volume. Double the low water volume should give double the channel depth*, and, at the same time, the ratio to high water is nearly halved. If normal flood is but five times the normal low water volume, the low water regimen should persist far better than if the ratio be ten. If such a radical change in condition will not improve a river for navigation, it is certain that removing half the low water volume will not injure it."

It will be noted that Mr. Cooley estimates the increase in low water depth as simply proportional to the general increase in low water volume, or in this case of the Lower Mississippi, say 8 feet depth for a natural low water flow of 100,000 cubic feet per second, then for a low water flow of 300,000 with the reservoirs, the depth would be 8 x 3 or 24 feet.

In his original paper, as a basis of estimates, the writer took the added stage from the reservoirs as a safe minimum. That is, say, 8 feet natural low water depths with 12 to 14 feet additional stage from the reservoirs, giving a 20 foot navigable depth at least in the new conditions. Both of these methods, however, assume that the low water regimen remains still a concentration of practically all the slope over the bars. If the new conditions result in a better distribution of low water slope, the increased depths will be correspondingly greater.

On the other hand while Major Townsend does not actually estimate this depth, he submits profiles of the Mississippi at various points from St. Paul to New Orleans, showing that in reaches where there is little slope the depth is good, while the shallow bars correspond to conditions of heavy slope in the river, both of which facts have never been doubted. But when he goes further and takes from this the case of a 2 foot low water depth at St. Paul, and a discharge of 2,000 cubic feet per second, with a 4.5 foot depth at Lake Providence and discharge of 100,000, and suggests the use of this as a ratio in which the additional depths may be reckoned for the 300,000 flow in the Lower Mississippi from the reservoirs, he loses sight altogether of the problem before him.

The question here is, "What would be the effect of a large, permanent increase in the low water flow of a river taken from off its high waters?" The same geographical name by no means makes the Mississippi at St. Paul and the Mississippi at Lake Providence the same river, and a large low water discharge in one river and a small one in another have nothing to do with the case. With the same depth and velocity the discharge is just fifty times as large over a bar 10,000 feet long as it is over a bar 200 feet long; but that does not mean that if the discharge in each case were tripled, the depths would not be very markedly increased; especially if this addition to the discharge was taken from off the high waters which give that spread to the channel in which the length of the bar is determined.

Now, the Mississippi at Lake Providence has about forty times the high water discharge of the Mississippi at St. Paul, and is about forty times as big a river, and the same low water depth there has naturally a much larger discharge to correspond to it. As clearly stated by Mr. Cooley, and as generally recognized, with other things equal, the spread of the channel is given by the volume of the high water; and it is this ratio of low to high water flow alone that depths in different rivers can be brought into any comparison. When Major Townsend ignores this in the matter presented, he omits the essential data required in it even to discuss his problem.

As bearing on the subject of erosion, Major Townsend presents the results of a number of velocity observations, especially the series in the Louisiana bend on the Lower Mississippi. In this he notes that the observed velocity near the bank is small at low water and what he calls a zero velocity at high stages, while between these, at stages about corresponding to the levels of the reservoir control, the velocity near the bank ranges between six and nine feet per second. From this he concludes that the reservoir control would actually increase the general rate of erosion on the Lower Mississippi.

Now, in this matter of erosion, there is unfortunately a lack of accurate data on the subject. It was at first simply a thing to be stopped by bank protection; it lay in that class of phenomena referred to by Mr. Cooley where it was taken, "That Nature had been guilty of an accident that only required man's intelligence to correct."

On the Lower Mississippi and Missouri rivers, however, when its annual average was fairly determined it began to raise some important questions. It was found that the banks were regularly caving in at a rate that would altogether fill up the low water channels in a few years, but for an equal and opposite movement of material in the yearly cycle up upon the slopes of points and bars and islands.

The forces of flow are thus engaged in the double process, at once a tearing down and a building up of the river channel. The one necessarily on the average the equal of the other; though bank erosion in such a river is practically a continuous action in one place or another through the year, while bar building must do the most of its work in the flood season. They do not then have their extremes of action coincident in time, but bar building can not stop permanently without erosion coming to the point where it would stop also; and continued bar building essentially depends on a fluctuation in the water level, for the flow can not raise material above its surface.

The writer has thus taken as a rough generalization, that the annual rate of this action, or the magnitude of this double process of erosion and bar building in an alluvial river, is, practically speaking, in some proportion to the vertical range in feet between its low and high waters. This is illustrated in the phenomena of different rivers. Thus the Mississippi river below Baton Rouge has but a fraction of the range between low and high water of the river above, with a markedly reduced rate of erosion there. True, it also has a markedly reduced slope; but passing to the case of the Platte river, with some twenty times the slope of the Mississippi, or six times that of the Missouri, it has a much smaller rate of erosion than either of them, corresponding to the range in level of only some two or three feet between its high and low waters. Again, on the Missouri and Middle Mississippi, with approximately half the range in stage of the lower river, bank protection has been reasonably successful, while a general bank protection on the Lower Mississippi has been practically abandoned. Doubtless, slope and the alluvial material of the river are factors in the magnitude of this action, but the prime cause seems to be simply its vertical oscillation in the season.

Aside, however, from the data of erosion and the general phenomena of these rivers, it may be certainly stated that if the varying discharge was entirely equalized, with no rises or falls whatever, any alluvial river would come in time to a condition of equilibrium, with no more erosion and no more bar building. If any one has any doubt of this he may turn a fixed discharge down an inclined plane covered with this material of the river bed and prove it. The conclusion, then, of Major Townsend, that a very marked approach to this condition in which erosion stops altogether would simply result in increasing it, is a big proposition to base on the data of a single section. While erosion in general is greater at high water than at low, there are places where it is found at low water and stops at the high stages, and with selected evidence of this kind anything can be claimed for it.

But even Major Townsend's section in itself is not conclusive evidence of the erosion there. What he calls a zero velocity seems to be the development of a high water eddy in the bend at that stage. Of course just what the bank was doing in this case the writer does not know, but he does know that an eddy may be one of the most serious forms of attack on a river bank to which it can be subjected. But in such details the discussion of erosion is endless. It is only in its totals over long reaches for seasons that it furnishes any evidence in the matter whatever. Now, the fact is, the proposed system of reservoirs will reduce the range between average high and low water from some 40 feet to about 17 feet, and the extreme range from some 52 feet to 27 feet. And in the matter of erosion there is certainly a big difference between the 17 and the 40 feet, both in the reduced forces attacking the banks and in their greater stability.

Finally, Major Townsend takes exception to the writer's reference to Lake Navigation and the Lake Control of the St. Lawrence water-shed. He notes that the St. Lawrence has a rock bottom, that Niagara takes up most of the fall, and that the parallel would be a dam some 300 feet high at Helena. Now, the writer in his original paper referred to the Lake routes mainly to note the commercial value of their 20 foot navigation. He did not look for an engineering criticism here; but since Major Townsend has offered one, it may be as well to remind him that in the Lake route referred to, there is the St. Clair river. That this river has not a rock bottom, and has something like the slope of the Mississippi—indeed in the narrows at Port Huron, even a larger one—and that the 20 foot navigable depth that is maintained in it is due to the reservoir control of the lakes above it. True, it is a short river; but the writer does not consider that things have to be made the same length to be made on the same principle. In the place of noting differences that were patent to all, and straining the parallel to the point of a plain impossibility, it might have been as well here to have looked into the matter simply for the evidence that it actually furnished of the good effects of a regulated flow in a river.

CXVIII.

PIERS OF MIDLAND RAILWAY BRIDGE, SHUBENACADIE RIVER, SOUTH MAITLAND, NOVA SCOTIA.

By Geo. E. Thomas, M. W. S. E.

Read April 3, 1901.

Our paper for this evening is on the pneumatic piers for Shubenacadie River Bridge. It is my purpose to bring before you some of the difficulties encountered and overcome in locating and sinking the caissons. This river may be called an arm of the Bay of Fundy, the tide coming in through Minas Basin and up through Cobequid Bay, rushes through the narrow passage with a velocity of 10 feet per second on the neap-tide to 15 feet per second on the spring-tide. There are two tides in twenty-four hours, and the peculiarity at this point being, that we have all the flow in two hours and thirty minutes, it taking nine hours and twenty minutes to run out ; also, that on the incoming spring tides we had a rise of seventeen feet of water in twenty minutes. This is known as the Bay of Fundy Bore. I have heard it said of its coming on a level plane of 8 feet. I never saw it over 2 feet, and I think the mistake is made by the

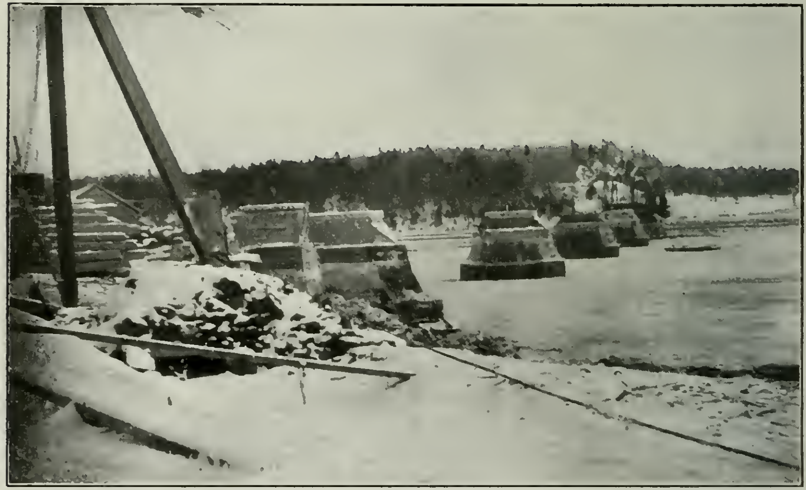


Fig. 1.

undulation caused by the tide striking the sand bars and making quite a wave; but I do not underrate the power of the tide in the Bay of Fundy.

The substructural work on this bridge consisted of two abutments, four pedestals and six river piers, and are located as follows: Starting from the west side of the river with a concrete abutment, 30 feet from the center of this was one pair of concrete pedestals; the next pair was placed at an equal distance from those; then Pier No. 1 was located just 30 feet east of those. Pier No. 2, or the draw pier, was located as shown on the plat as 42 feet from center of pier No. 1, and the other piers were 219.50 feet from center to center, and the east abutment was the same distance from pier No. 6.

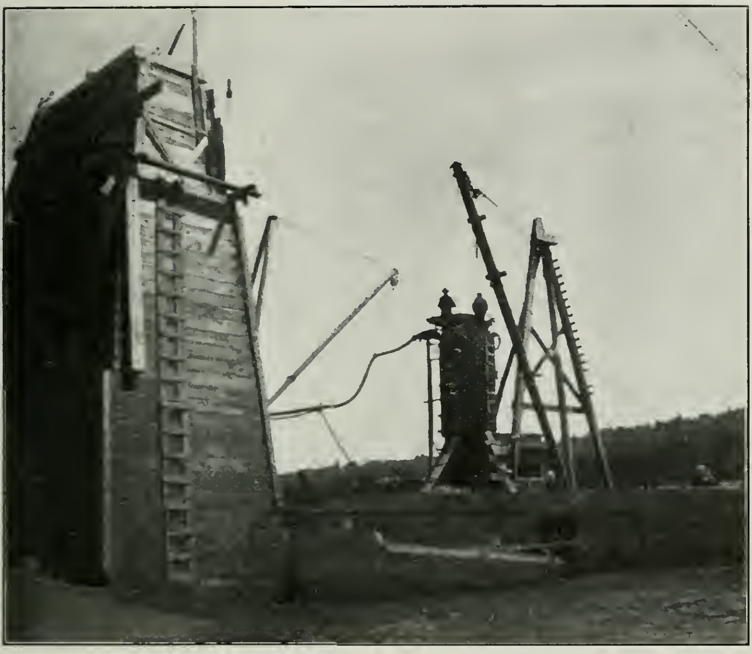


Fig. 2. Pier No. 1.

We started work on the west abutment and found a soft shale rock cropping out; we excavated through this about 12 feet to a hard rock bottom; on this was placed the concrete, bringing this up to surface of ground, and then placing the mould and building up the work to the proper elevation. The same course was followed with the pedestals.

Pier No. 1 begins at low water and was built up in the open.

We had considerable difficulty in preparing the rock under this pier, as it was very uneven, and we had only a period of one and a half hours in which to work on each tide. We succeeded in making a true and practically level bottom on the hard rock, into which we drilled and put in a number of anchor rods, to which was fastened the first course of crib timbers to the rock, consisting of 12x12 inch white hemlock timber. It was slow work, as it had to be very carefully done in order to secure success. After this course was securely fastened, it was much less difficult to care for the courses above, each being drift-bolted to the one below. Hemlock timber was used only up to ordinary low water, and above this point we used what is known in that country as Bay Shore spruce.

When this crib was built up three feet and calked, we put in the first two feet of concrete. The reason for starting so early on this filling was that we could not put in on the low tide more than this quantity. The time was so short during low water, before there was a return of a very rapid tide water, bringing with it a heavy body of sand and mud, and before this came we had to protect the new made concrete by very carefully covering it with canvas, placing on this large stones and filling in between those with small ones to break the force of the incoming water. We learned several lessons before completing our work. This pier, No. 1, was formed differently from the others, it being rectangular. The purpose of this was to enable a protection to be built against it to keep off the ice, etc., during the winter. This crib was not completed last season, winter coming on before it could be done.

The first pneumatic pier to be put in was No. 6, and was the one on the Colchester county or east side; the plans of piers and the profile showing the bed rock, etc., were furnished by the railway company's engineer. This profile proved faulty, as the rock did not materialize at the points indicated. Low water was shown at a given elevation, and immediately under the bottom of this pier No. 6 the rock was shown to be too close to enable us to put on a timber roof and have this submerged, as we required at least six feet for a working chamber in a pneumatic caisson.

With the consent of the chief engineer I decided to build up the walls of the caisson 10 feet high, putting on a roof of two courses of 12x12-inch timber, lined with 3-inch spruce plank, and calking the seams, fitting up air and supply shafts, and building up a temporary crib around the sides and ends, and loading this with rock to overcome the uplift of the tide. After reaching the bed rock we removed this temporary roofing, etc., and carried up the concrete continuous to the bridge seat. This involved a large amount of extra work, but we did not consider it safe to put in a timber roof that would be exposed to the climatic changes and subject to rapid decay. However, I found upon reaching the point indicated as rock on the profile, that we had still nearly 3 feet deeper to excavate in order to reach bed rock. This greater depth, if known in advance, would have enabled me to put in a permanent roof on which we would have built up the permanent concrete, thus not only saving labor, but very valuable time. Immediately overlaying the bed rock under this pier we found a hard conglomerate, embedded in which were large boulders, making it a hard material to excavate.

Our next pier was No. 5. This was located 219.50 feet from the center of No. 6 and about 500 feet from shore. The caisson for this pier was built to pass through the class of material indicated on the profile, that is a soft material permitting rapid sinking; but in this we were disappointed, as from start to finish we encountered an entirely different formation to that represented. Not only was the material which we passed through different to that represented, but we had to go about 14 feet further to find bed rock. This, of course, meant a great expenditure of time and money, especially in such a river as the Shubenacadie.

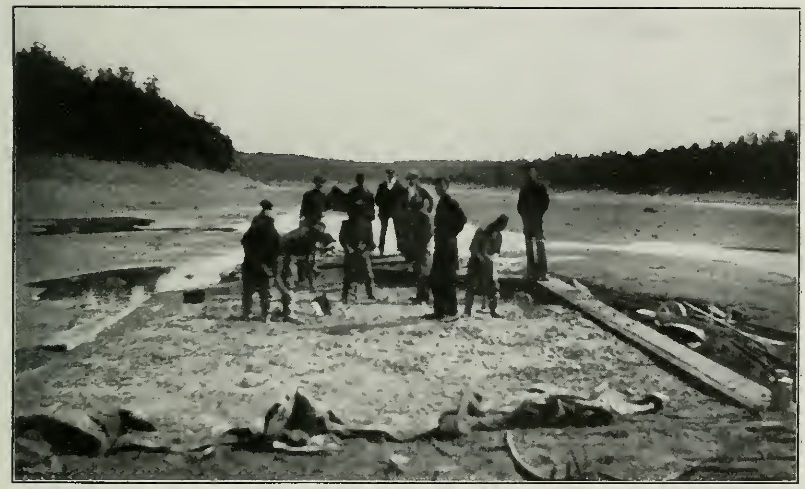


FIG. 3. Pier No. 6, Temporary Roof Removed.

We met with a strange accident in the early stage of sinking this caisson. The tide was due in one-half hour and the men were getting ready to come out, as I never allowed the men inside the caisson when the tide struck the site. This caisson was out on a sand-bar, and the tide was so low there was absolutely no current at this point at the time; and as there was only four feet of water in the working chamber, there was a very light air pressure. Due, I think, to some carelessness, the two doors of the air lock were allowed to be opened at the same time, and in this way there was a rush of water into the body of the caisson which so frightened some of the men, they made a stampede for the shaft, each trying to get there first. I was informed by some of the older pressure-men, who were not frightened and who stood their ground, coming out after all the trouble was over, that if the men had kept cool all would have been well. However, we are not all built on the same lines, and we would all be better men were our first thoughts equal to our second. We lost four men, this number being taken out dead. In three minutes from the time the air was lost from the chamber everything was again in working order and the water was out of the working chamber. In fact, it was not realized that four men were injured until they were found in the bottom of the caisson chamber. The accident was thoroughly investigated by the coroner, a competent jury and the friends of the deceased, and all exonerated the contractors. I would say there was not any change made in any of the machinery or appliances after the accident, the men showing implicit confidence in the system by returning to work as soon as the bodies had been shipped to New York, except one who was buried in a little church-yard near the bridge site, and who, I was informed, had been a soldier in Her Majesty's service at Halifax. His fellow workmen erected a very handsome stone over his grave, giving an account of the accident.

We experienced much difficulty in getting this caisson to the bed rock, having to take it about 14 feet deeper than indicated, through a very hard tenacious material, which necessitated the use of a large quantity of dynamite. We could not make much impression on it with ordinary picks, and had to resort to drills, steel bars and explosives. However, we finally reached bed rock, and made a first class concrete pier.

We next went over to pier No. 2, which is the draw pier and is located about 42 feet from the center of pier No. 1. It will readily be seen that the opening for vessels to pass is small. On this pier No. 2 will rest the small jack-knife draw. We experienced great difficulty in getting the rock under this pier level enough to receive our caisson, as at low water there was only 2 feet 6 inches of water at one end and nearly 12 feet 6 inches at the other. This necessitated doing some under-water drilling and blasting before bringing the caisson down. The point of location of this pier was the most difficult to do this work in, as it had to be done at extreme low water, and the lower the water the greater was the concentration of the tide. The incoming tide, in time and force, depended somewhat on the direction and force of the wind in the lower bay that would cause it to vary as much as thirty minutes between some tides. One day it came up so much before it was expected, it washed away our steam drills and tools, swamping the heavy working float that was held by heavy steel wire cables. This float came up after the tide slacked up, but the tools were never seen afterwards. There is no use trying to handle these tides during the strong run. After a hard fight and persistent effort we finally got this rock so levelled up by the use of stone and clay thrown in on the slack tide from our cable bucket, that it was possible to put this caisson in position and get enough weight on top to hold it down. This enabled us to get inside of it and level the rock, taking the caisson down through the temporary filling and making a first class job. We filled the working chamber and completed this pier up to the coping, none of which was set, however, until the concrete was well settled.

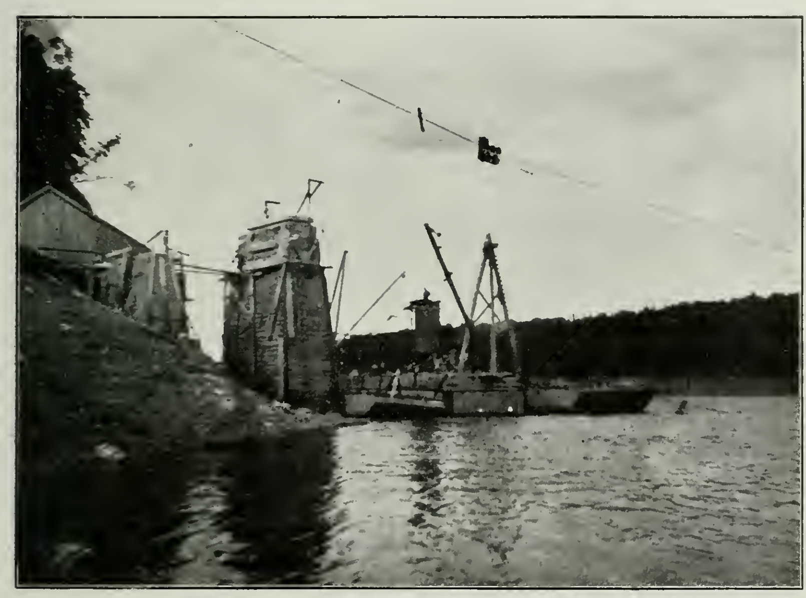


Fig. 4. Pier No. 1 and Working on Pier No. 2 for Draw Span.

The next pier was No. 3, and with this one we had the least trouble. This is not saying it was easy work, but we had been well drilled into the work with the others by this time, that this one seemed comparatively easy.

After the experience I had with the material and location of bed rock in No. 5, I concluded I would alter the form of the cutting edge and strengthen the caissons for piers No. 3 and No. 4.

This was done by putting on the outside a course of vertical timbers, 12 x 12 inches, letting them extend down about 12 inches below the other side timbers, and bolting them through into the working chamber; putting in extra through rods, etc., etc. We got No. 3 to bed rock and filled with no more than the to be anticipated amount of trouble. This, however, was the calm before the storm. We started in on No. 4, the last of the caissons, and which was known as the "Z. I. Fowler," named after the chief engineer of the Midland railway. This caisson was launched and taken down to the bridge site in good time and without accident, getting it out into position, and leaving it about 12 feet above the direct center line of the bridge. We did this to enable us to put on the first lot of concrete, as the flotation of the timber in the caisson was so great, and the time between the tides so short, we could not get weight enough on it in one tide to hold it down. We used two day-light tides to do this work. We put in all the concrete we wanted on the first tide, the caisson riding safely over the night tide. The next morning we located it exactly in position and were anxiously watching it settle. At this time the water was passing freely over the sand-bar directly above us; this seemed to stop instantly and the bar was exposed; this caused the water to strike the west bank of the river, concentrating the full force of the falling tide against the upstream west side of the caisson, which parted the three steel cables and forced the caisson out of position, and in five minutes it was hard aground 8 feet out of position toward the east. All the moving cables were rigid except the broken ones. These we had to renew and the others to slack up before the tide came again to allow the caisson to rise with the incoming tide. This it did successfully; but before we could get down to renew the broken side cables, the sand-bar had been removed, due to the presence of caisson above it, causing a very great concentration of tide under the working chamber. This caused the structure to roll over, bottom side up, and I thought, perhaps, the concrete which had been put in would roll out, but in this I was disappointed. You will notice there are times when it does not pay to use an extra quality of concrete. I knew the caisson could be rolled back, but the same conditions would exist, and the momentum of rolling would have to be cared for. I concluded to try, as we might succeed. We put on the purchase and rolled it back, but it kept rolling. At once I decided to remove the caisson to the shore, if possible. All the cables except the inshore upstream one were cast loose and allowed to drag on the bottom, and thus steady the caisson as it flanged to the bank. It did all I anticipated it would, until the mooring gear, which was now on the under side, caught in one of the large anchors, which brought too much strain on the cable and parted it. The caisson then floated up the river on the strong flood tide, and we followed it in our yawl boats and with strong manila lines. We rowed much faster than the caisson drifted, and securing a 1,000-foot line to a tree on shore, we rowed out to meet the caisson, and in this way navigating it into slack water, then landing it until the returning tide, when, with the assistance of our tug boat, we took it on the early ebb tide to our building yard, there taking out the concrete, using dynamite. We then wrapped four 1⅝-inch steel hawsers around the caisson, two each way, and led these on shore. Putting a heavy purchase onto each, and taking the hauling parts to separate engines, we rolled the caisson back into position. Notwithstanding the fact this caisson had endured such hard usage, it was but very slightly damaged. We at once made the necessary repairs and prepared to get it into position, which we did with perfect success. We experienced a new difficulty in filling this crib on this caisson. Every pier put in, reducing the opening for water passage in the river, seemed to act like so many wedges, and made the current more violent in the openings. During the spring tides it seemed next to impossible to keep the new

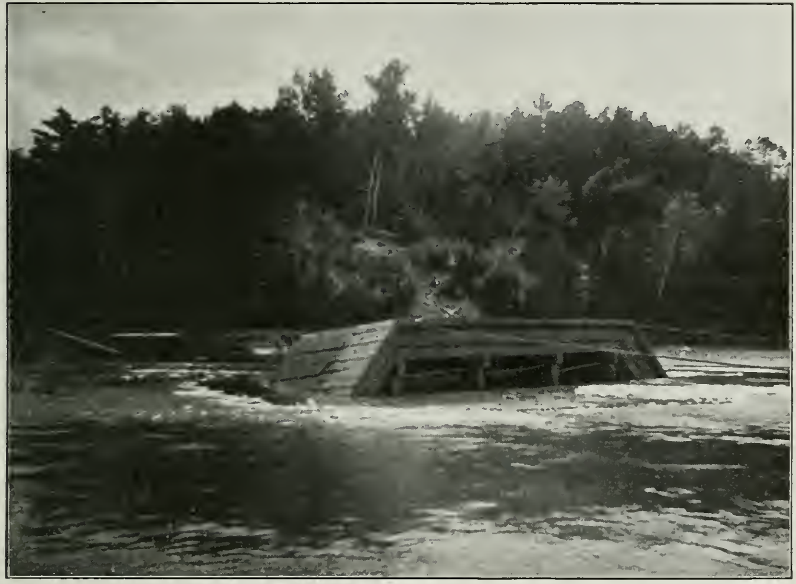


FIG. 5. Caisson for Pier No. 4, being rolled over.

concrete from being washed away. This happened several times, and we would lose the result of a day's hard work. We finally abandoned the use of canvas and used woolen blankets. Those seemed to conform more to the concrete, and in this way we managed to get above the tide. We found it was better to keep the concrete close up to our cribbing, thus preventing the scouring action of the water falling over the top of the crib. By watching the changes of the current in the river, I was enabled to so place my direct cables that in this way to hold this caisson that had once gotten away from me. It certainly was a very trying and anxious time, and I want to say the men who stood by me through the placing and sinking of those caissons did their full duty, and I assure you it was a very nerve-trying position. The plan adopted by me to locate those caissons was, first, to take the caisson down from the building yard to the mouth of the five-mile river, which was about 300 yards above the center line of the bridge. In order to do this, we had to start at certain periods on the tide, there being so many changes of the current in this river. The distance from the building yard to the bridge site was only one mile, but there were so many swirls and eddies we had to keep lines on shore the whole distance and check up on the cable at the lower end. Another strange feature of those tides is, that the body of water would be falling and still a very strong current on the surface running up; and at a certain time of each tide, without any notice, the the whole river would be running out with apparently irresistible force, and if not prepared for this you would move down stream with it. We were taught more than one lesson this way. There is absolutely not over thirty minutes on the top of high water when you can handle any floating stock at the site of the Shubenacadie bridge. I saw this upon my first visit to the bridge site, and concluded to use a cableway across the river, the distance being about 1,400 feet. I put up two towers. The one on the west side was built on the marsh bank, and was about 85 feet above low water, while the one on the east side was built on the bluff, and was about the same height above the water, though the tower being on higher ground was shorter in the posts. Those towers were very strongly built. I also took the precaution of putting some wire guys to the heads of the towers. We did this to guard against the wind strain which came up with the flood tide, sometimes with considerable force. We used a 2½-inch diameter Lidgerwood cable with the ordinary working steel wire ropes. The main cable was anchored back in the ground, the end on the west side being held in marsh mud. With this we had to be very careful, and to overcome any possible chance of it giving way, we used as an anchor four very large hemlock logs buried in a deep trench, the front of the trench being planked up with 3-inch plank. The main sheave for passing the main cable through was securely lashed to those four logs with ⅞-inch flexible steel wire rope, each part being brought to a proper bearing, and giving each part its share of the load. We loaded the surface of the ground with field stone. This cable never moved or gave me any trouble, and we have handled between tides as high as 116 buckets of concrete, each bucket containing 32 cubic feet.

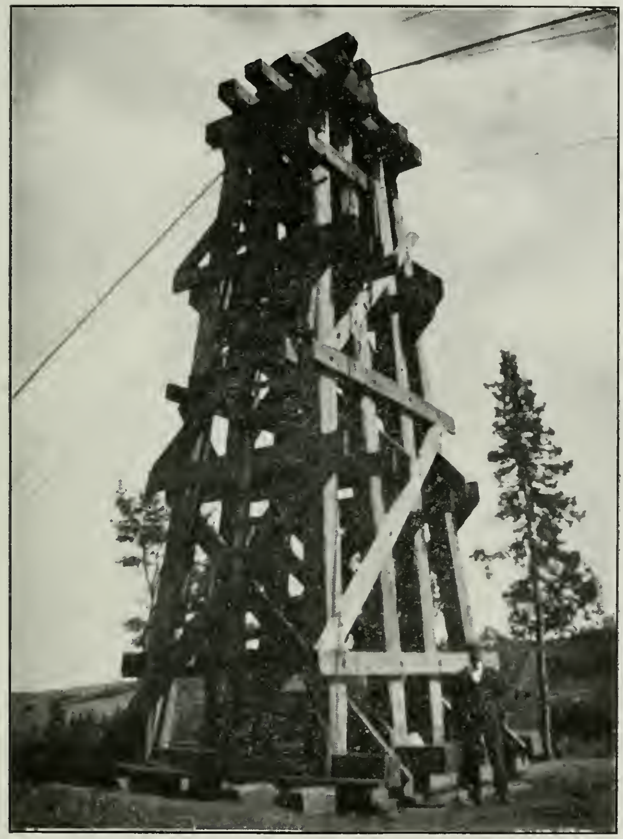


FIG. 6. Tower Supporting Cable Railway.

The machinery never gave me any trouble further than the ordinary wear and tear of machinery driven under such hard work as this was. I cannot speak too highly of the cable system. I would not say this work could not have been done in any other way, but I would not like to try any other way known to me. We had quite a time getting the main cable over, as the ever-present tide came on us when we were about two-thirds way across; but we completed our task without accident. We also experienced great difficulty in getting our supplies for the work; the stone for concrete was quite a problem. We used large quantities of small boulders which had been washed down the river, and we also found a vein of about 5 feet of quartzite on the river bank, which we quarried when the tide would allow. You see the tide enters into all our arrangements.

The cement selected by the Dominion Government Engineer was the White Brothers brand of England, which was there manufactured and shipped to Halifax by steamer, and from Halifax to Stewiacke siding by rail, unloaded again and taken down to the bridge site in small scows, the distance being about 12 miles.

The sand-bars are so numerous and change so often one cannot take up a boat with more than 2 foot draft, and this has to be handled with sweep oars and only make from three to four trips per week, up on one tide and down on the next, if you are not nipped or caught. You see the tide is omnipresent. The sand for our concrete was another problem for the same reason. We had to go 50 miles to Five Island Point to get a good and acceptable sand; and this we had to get in schooners, as it is sometimes very rough on the bay. The gravel which entered into the concrete largely had to be boated on the tide from De Bert beach, a point about 16 miles down the bay, and only small barges could go after this on account of sand-bars. We had a small tug we sent several times, but we generally had complaints from the captain about the risk. Our coal was quite an item, as this had to be brought either from Passboro or over the Intercolonial railroad to Stewiack, and then barged down to the bridge site. It was a common occurrence to see the barge with coal or cement pass the site, going down stream, the tide being so strong they could not make a landing. Even the water for the boilers had to be boated to the site, about 2 miles, in barges, and only make one trip with each barge on a tide. We had to stop sinking the caisson on more than one occasion on account of lack of fresh water for the boilers.

We moored the caissons with not less than six steel wire cables on each, those being not shorter than from 600 feet to 1000 feet each, and fastened to either large anchor cribs filled with rock on a sand-bar, or to anchor bolts put into the rock in the river bed. The cables were fastened with clips to those and attached to the caisson by a specially devised mooring gear. After the caisson had been properly weighted with concrete we would put our machinery barge alongside, mooring it in a similar manner. We would take our water barge alongside the machinery barge and pump the water out as rapidly as possible. We lost all of the barge load of fresh water on several occasions by the tide breaking in over the water scow. We tried on one occasion to bring coal off on a barge and use it from this barge, but the incoming tide settled this point by standing the barge on end, dumping the coal, then fouling the moorings and breaking the barge into two parts. After this I ran all the coal out by the cable way, which added much more work to our already hard worked cable.

Machinery, derricks and barges were built by us as strong as wood and iron could make them, knowing as I did the rough usage they would have to encounter. In the barges I used hardwood frames and spruce sides, strongly trussing them throughout; they were 80 feet long and 22 feet wide, and 7 feet 6 inches deep, with a good flare at each end. The mooring timbers were very strong, of 14 inch by 14 inch hardwood and with a very heavy warping chock on each end. All of which was necessary, as we not only had the racking of the machinery, but the sandbars were so changeable that, generally, at low water, the barges would be on the bottom and very unevenly landed. Our machinery consisted of an ordinary pneumatic plant, viz.; compressors, pumps, boilers, electric lighting machinery, etc. We also had in the hold of the machinery barge a large number of barrels connected with pipe, which we used for water storage, the plant being very compact. Our derrick barge was a duplicate of the machinery barge; it was surmounted with a very strong derrick and carried an 8¼ inch by 10 inch double Lidgerwood winding engine. The coping stones for those piers were quite heavy, four on each pier weighing over 8 tons each. Setting those stones with a long boom was no child's play, with the strong running water that was there. We also had several derricks along the wharf on shore, also at the shipyard where we built the caissons and one up the river at Stewiacke. This work called for more machinery than ordinary work does, due to the time of still water being so limited for loading or unloading supplies.

Our caissons were built of 12 inch by 12 inch white hemlock, and were 62 feet long, 26 feet wide, and had 8 feet of working chamber. The sides were three feet thick, all drift and through bolted, lined on the inside with 3-inch spruce and calked, also braced across and through with 1½-inch rods put in from side to side. A hemlock roof 3 feet thick was planked over and the seams calked. From this point we started our crib work, this also being calked on the outside. They were built sharp on each end, and each of the ends were faced with hardwood 6 inches thick, which was fastened on with 5/8-inch steel drift bolts; then the nose and shoulders were faced with 3/8-inch steel plates, fastened on with 3/4-inch iron rag bolts. The cribbing was 12 inch by 12 inch Bay Shore spruce. We did not use any timber ties, but in place used 1 1/4-inch through rods with turn-buckles. There were four of these put in every third course of timber.

Our concrete was of two classes, viz., hearting and facing; this was mixed on a platform on the west side of the river under the cable way and transferred out to the various piers. In all cases Portland cement was used. We also built into the concrete, hook rods made of 3/4-inch round iron, which overlapped each other, thus making a continuous bond. These were put in vertically and horizontally. This work was designed by the chief engineer of the Midland Railway Company, Mr. Z. I. Fowler of Ottawa, Ont. Mr. Fowler is a very able engineer, and of whom I cannot speak too highly. I must say that I found in Nova Scotia a warm-hearted and energetic people, ever ready to extend the hospitality of their homes and hearts to us.

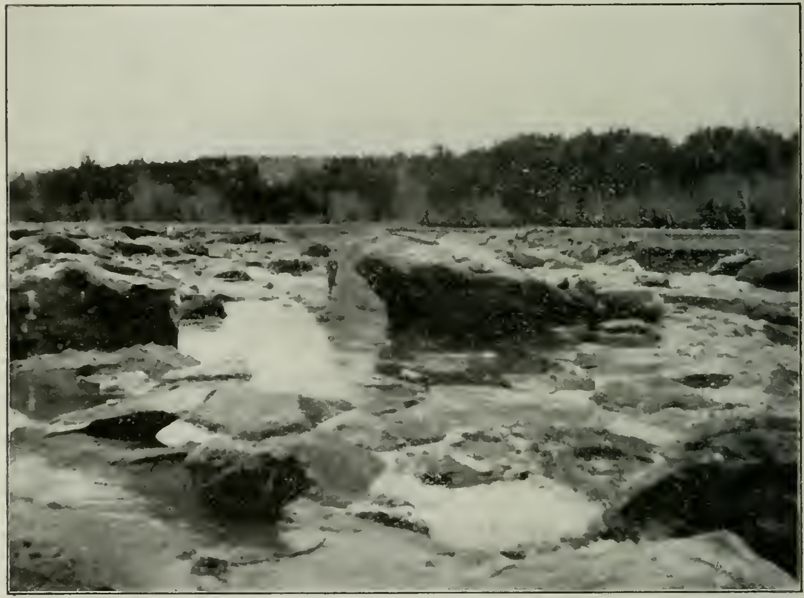


Fig. 7. Ice Formation.

All railroads in Canada are subsidized by the Canadian Government; this road is by the Dominion and Provincial Government, consequently we were under the supervision of the Government engineers, Dr. Martin Murphy of Halifax being the Provincial engineer I had most to do with, and I found him to be a very able and competent engineer.

DISCUSSION.

Mr. Finley—In describing the foundations for one of the piers Mr. Thomas mentions that there was a hard material that was very difficult to remove. Why was it necessary to remove it?

Mr. Thomas—I will simply say that what has been might occur again, and it was very evident that at some time the river bed was down at bed rock, and at some time in the future the water might go down again to the bed rock. I can never do my work too well, for I realize that human life is concerned in the integrity of the foundations of these piers.

Gen'l W. Sooy Smith—What appears to me most singular, in Mr. Thomas' talk this evening, and what might perhaps invite criticism (which would not be in good taste in the absence of those who designed the work), in the light of American engineering, is the fact that the bridge should have been planned as it was, and that there should have been such a lack of knowledge of the conditions under which these foundations have been built, and even the material itself upon which they were to rest was not well known. The soundings also proved deceptive. It would certainly appear that that, of all situations, was one in which a long span would have been advisable, first, on account of the extreme difficulty of putting in the piers, and second, because of the obstruction of the piers themselves. Great ingenuity was called for on the part of those conducting this work, as has been made evident to us. The greatest difficulty was imposed upon them, and it seems to me to have been, to some extent, unnecessary, if a thorough knowledge of the work had been obtained in the first place. If a plan of substructure had been made, adapted to the superstructure and adapting itself to the existing conditions, the difficulties would have been very largely reduced and the final result, it seems to me, very much better.

Mr. Thomas—With regard to the proper soundings being taken, it was what we have all met with and will meet with again, namely, they did not allow the engineer, in the first place, sufficient money to make the necessary examination, and more than that, the man who did make it had evidently never done any of that class of work before, as in place of making "borings" he made "drivings." He drove a rod down; he said he could not turn his pipe down.

I made some surveys for the Roberts-Corbin Syndicate when I was in the employ of Sooy Smith & Co. It is not generally known, but I made all the borings and all the surveys in New York harbor from Cortlandt street to Ft. Tompkins and up the Kill von Kull, for the proposed tunneling, etc., which is to be done under New York City. I went down over 266 feet to rock, using only a 1¼-inch pipe. I went down 104 feet through boulders and very hard material, and there is no use telling me a man cannot put a pipe down where he wants to, if he understands his business.

Mr. Strobel—I would like to ask what are the dimensions of these piers?

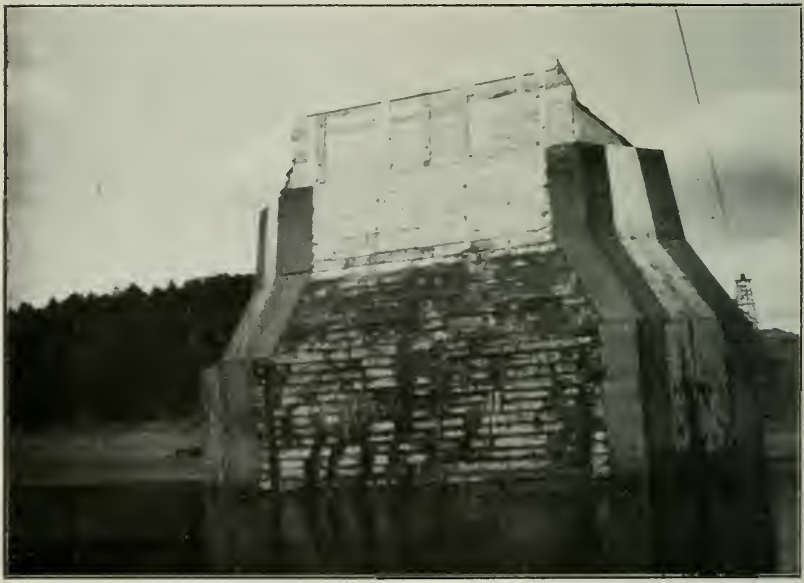


FIG. 8. Pier Showing Protection Plates; Moulds not yet taken down at Upper Part of Pier.

Mr. Thomas—Size under coping, 24 feet long by 8 feet wide; coping, 2 feet thick, of granite.

Mr. Strobel—What batter?

Mr. Thomas—On the lower part on the first 12 feet, 6 inches in 12 inches on the ends; and on the sides, 1 inch in 12 inches for the first 12 feet, and ½ inch in 12 inches from there up.

Mr. Finley—Is it not a matter of fact that we have always had considerable difficulty in borings and soundings on account of the inaccuracy of locating rock?

Mr. Thomas—I do not know that it is. I did some work for Mr. Morison, and I do not think I varied ¼-inch there. I think a man should ascertain, as General Smith has said, the exact location of the rock. I have never heard of any of Mr. Morison's borings being found faulty. The borings that were made across the Colorado River, at The Needles bridge, were made by competent engineers, but they did not strike it correctly by 40 odd feet.

Gen. Smith—As there are a good many young engineers here this evening, I will say that there is nothing, it seems to me, more important, in preparation for the building of any bridge, than to ascertain, with the greatest accuracy, all the conditions and surroundings, not only with regard to the difficulty of doing the work, but the good judgment to be exercised in planning it. Very often economical methods can be used when you know perfectly the conditions with which you have to deal. Those of us who are gray-headed have learned these things by sad experience, and here is a notable example of a very great deal of difficulty growing out of the want of knowledge of the conditions and want of adaptation of the plans to the conditions.

Mr. Thomas—I would like to say that sometime ago I put up a lighthouse on the coast of the Bay of Fundy, near the New Brunswick line, and the specifications read something like this (it was for the Government): Seventeen feet of water; cylinder was to be landed and then dredge out about 5 feet of soft material on the surface, when there was to be 18 feet of concrete put in and then pumped out. I went up there to find out all I possibly could in regard to the conditions, and from the condition of the material I found there I concluded that it was no place to put a lighthouse, 75 feet above water. I called the Government's attention to it, but they simply ignored me and thought I did not know what I was talking about. I finally decided to write to my firm in New York, and had no further trouble, as I received instructions to go ahead and do what I had proposed. In place of going down 5 feet, I drove piles in that cylinder 76 feet long, driving piles which I had to splice. Some days we would drive one pile and some days not any, but I put the lighthouse up, complete to the lantern.

Mr. Finley—I recall a case of a foundation, a few years ago, where the engineers located rock within six feet of the bottom of the river; this was done by two engineers at different times, so we thought we had a pretty sure check on it, and yet we drove 30-foot piles in each foundation.

Mr. Gerber—I would like to ask the chairman why he thinks the Missouri River is a particularly easy place to locate rock. I have had a little experience there and in one place we failed to locate it.

Mr. Finley—I think so by comparing it with other places.

I was under the impression that in the Missouri River it would be somewhat easier to definitely locate rock.

Mr. Gerber—In about '87 there were some borings made in the Missouri River near Sioux City, which were made in pretty good shape. I saw the work being done at various times, and I think they went down 130 feet and did not find any rock. Two years after, I made some more borings at the same bridge. My predecessor, who made the first borings, found clay at a depth of forty feet, and after going through five or six feet of clay he encountered sand until he got to the bottom of his borings. I did not find any clay at 40 or 50 feet; I did find clay at 90 feet. The only thing in which our borings agreed was that we had no rock at 140 feet, and subsequently we put down four caissons and then the difficulty with the borings was very easily explained. When we got down 50 feet we found plenty of clay, some of it in chunks 15 feet square, but in between these pieces of clay there would be fissures of sand six or eight feet wide; and as to rock, when we got down about 70 feet we found plenty of large boulders, on which we could have landed with our pipe and found what we might have supposed to be rock.

ERRATUM.

On page 64, Vol. VI, February issue, 1901, fifteenth line from bottom of page, for "Mr. Finley" substitute "Mr. Reichmann."

ABSTRACT OF MINUTES OF THE SOCIETY.

SPECIAL MEETING, February 27, 1901.

A special meeting (No. 443) was called for the 27th of February, in accordance with a resolution passed at the meeting of February 13, 1901, for the further discussion of the "River and Harbor of Chicago." Owing to the absence of those expected to speak on the subject, the meeting was not called to order, but converted itself into a social gathering and a smoker.

REGULAR MEETING, March 6, 1901.

A regular meeting (No. 444) of the Society was held in its rooms March 6, 1901.

Mr. W. H. Finley, 1st Vice-President, in the chair, with about thirty-five members and guests present.

The Chairman announced that, if there would be no objections, the reading of the minutes of the preceding meetings would be dispensed with, as they would be found printed in the JOURNAL, and would be in the hands of the members in a few days.

The Secretary read from the minutes of the Board of Direction, held March 5, the names of those elected to membership:

Active Members—

R. B. Stearns, 1527 Kenmore avenue, Chicago.
Jewett Darling, 239 76th street, Chicago.
E. J. Steinbeck, Freeport, Ill.
W. K. Means, 456 Jackson street, Milwaukee, Wis.
W. D. Taylor, 2107 W. 36th street, Chicago.
Jno. McIntyre, 4114 Ellis avenue, Chicago.
Alberto Bement, 218 La Salle street, Chicago.
Jno. H. Sutter, 733 Chicago Stock Exchange, Chicago.
O. H. Vanderlip, 163 Randolph street, Chicago.
Geo. A. Damon, 1540 Marquette Building, Chicago.

Junior Members—

H. C. Lothholz, 31 Lake View avenue, Chicago.
Jno. F. Icke, 317 W. Mifflin street, Milwaukee.
Wm. Artingstall, 13 Hamilton avenue, Chicago.

The Secretary also read the following list of names who had presented petitions for membership in the Society:

C. McD. Townsend, U. S. Engineers, Rock Island, Ill.
C. Schroeter, 222 Evergreen avenue, Chicago.
Wm. Seafert, 161 La Salle street, Chicago
R. W. Carter, 3953 Michigan avenue, Chicago.
A. J. Caldwell, 5202 Kimbark avenue, Chicago.
H. M. Ely, Rockford, Ill.
R. B Ketchum, 686 W. Adams street, Chicago.

There being no other business before the house, there followed the discussion of Mr. Boardman's paper on the "Substructure of the Glasgow Bridge." The lantern slides prepared to illustrate this paper were shown with a short explanation from Mr. Boardman. Gen. Sooy Smith followed with an account of the construction of the first Glasgow bridge, "the first steel bridge in the world," and also of the "Hay" steel used, its testings, etc. Mr. Geo. Thomas followed with some information as to the substructure and foundations. Mr. Taylor also spoke of the old bridge, and Mr. Finley spoke of his experience with "Hay" steel.

At the conclusion of the discussion of the Glasgow bridge, Mr Jas. A. Seddons gave a reply to the paper of Maj. Townsend, of the U. S. Engineers at Rock Island, in which he had discussed Mr. Seddon's previous paper, XCVI, "Reservoirs and the Control of the Lower Mississippi."

At the conclusion of Mr. Seddon's remarks, there being no further business, the meeting adjourned.

SPECIAL MEETING, *March 20, 1901.*

A special meeting (No. 445) of the Society was held in its rooms on March 20. Mr. W. H. Finley, 1st Vice-President, in the chair, and about forty-five members and guests present.

The meeting being called to order, the Chairman announced the recent death of a member of the Society, Prof N. O. Whitney, of the University of Wisconsin. He then introduced Mr. F. L. Wright, an architect of this city, who read a scholarly and suggestive paper on "The Art and Craft of the Machine," which was illustrated by lantern slides of certain notable buildings, complete or in process of construction. In the discussion which followed, Mr. E. Lorch, of the Art Institute, seconded some of the points of Mr. Wright's paper, and stated what was being done at the Art Institute along the same line of education. The Chairman and Prof. Chamberlain, of Lewis Institute, also took part in the discussion. On motion from Mr. F. L. Hill, it was decided that further discussion of Mr. Wright's paper would be held at some other meeting in the future, as may be decided by the Publication Committee. Mr. Reynolds offered a motion, duly seconded and carried, that a committee of three be appointed by the chair to draft suitable resolutions on the death of our late member, Prof. N. O. Whitney.

After the meeting adjourned refreshments were served.

MINUTES OF REGULAR MEETING, *April 3, 1901.*

A regular meeting (No. 446) of the Western Society of Engineers was held in the Society rooms the evening of April 3, 1901, Vice-President W. H. Finley in the chair, and about fifty members and guests present.

On motion, the reading of the minutes of the previous meeting was dispensed with.

The Secretary presented a report from the Board of Direction as to the election of members as follows:

For Active Members—

Wm. H. Pearce, 84 Adams street, Chicago.
John Van Wakeman, 383 Ontario street, Chicago.
C. Schroeter, 222 Evergreen street, Chicago.
R. W. Carter, 3953 Michigan avenue, Chicago.
A. J. Caldwell, 5202 Kimbark avenue, Chicago.
R. B. Ketchum, 686 W. Adams street, Chicago.
C. McD. Townsend, Rock Island, Ill.

Associate Member—

Wm. Seafert, 161 La Salle street, Chicago.

Junior Member—

H. M. Ely, Rockford, Ill.

Applications for membership were presented as follows:

Active Members—

L. P. Friestedt, 145 La Salle street, Chicago.
F. W. Hawks, Ellsworth Building, Chicago.
Chas. L. Hall, No. 1 W. Kinzie street, Chicago.
L. P. Yale, 5520 Ohio street (Austin), Chicago.
Albert Scherzer, 1616 Monadnock Building, Chicago.
J. B. Taggert, Delaware, Ohio.
V. K. Hendricks, Terre Haute, Ind.
C. T. Dike, Peoria, Ill.
A. W. Merrick, Eagle Grove, Iowa.
D. C. Rounseville, Kaukauna, Wis.
R. E. McDonnell, Kansas City, Mo.
W. C. Armstrong, Boone, Iowa.
H. E. Stannard, Barraboo, Wis.
R. C. Sattley, Wheaton, Ill.

For transfer from Junior Grade—

W. G. Kirchoffer, Barraboo, Wis.
F. G. Vent, 89 E. 44th street, Chicago

Junior—

A. S. Rosing, Buda, Ill.

There being no further business, Mr. Geo. E. Thomas, a member of the Western Society of Engineers, was introduced, who read a paper on "The Piers of the Midland Railway Bridge over the Schubenacadie River, Bay of Fundy, Nova Scotia." This was illustrated by numerous lantern slides,

Discussion followed from Messrs. Finley, Wm. Sooy Smith, F. L. Hill, Strobel, Gerber and Thomas.

The meeting then adjourned.

MINUTES OF SPECIAL MEETING, April 17, 1901.

The special meeting (No. 447) of the Western Society of Engineers, held April 17, 1901, was called to order by Vice-President W. H. Finley, in the Society rooms. About ninety members and guests were present.

As this was a special meeting, there was no business transacted; but Prof. S. B. Newberry, of Sandusky, Ohio, was introduced to the Society by the Chairman, who gave an interesting address to the Society on "Some Engineering Problems in Cement Manufacture."

There were a number of lantern slides and also an exhibition of samples of the raw material and finished product to illustrate the lecture.

Discussion followed, particularly along the lines of testing of cements, from Messrs. T. T. Johnston, Boardman, Wisner, Bergquist, Finley, McHarg and Warder.

The meeting then adjourned.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

Nova Scotian Institution of Science, paper, Vol. X, pt. 2, Proceedings and Transactions, Session 1899–1900.

State Board of Health of South Carolina, 21st Annual Report for year 1900.

Massachusetts Institute of Technology, Paper XI and XII, Result of Tests made in Engineering Laboratories of the M. I. of T.

Edward A. Bond, State Engineer and Surveyor of New York, paper, Report on the proposed Barge Canal from the Hudson River to the Great Lakes.

Munn & Co., New York, N. Y., 1 vol., cloth bound, Scientific American Cyclopedia of Receipts, etc.

Board of Trustees, Commissioners of Water Works, Cincinnati, Ohio, 1 bound volume, Report of Water Filtration, 1899.

Board of Trustees, Commissioners of Water Works, Cincinnati, Ohio, 3 vols., cloth, Annual Reports of Cincinnati Water Works, 1898, 1899 and 1900.

Hon. Jas. McMillan, Washington, D. C., 1 vol., cloth, Senate Report on Purification of Washington, D. C., Water Supply, Washington, 1901.

Metropolitan Sewerage Commission, Boston, Mass., 1 pamphlet, 12th Annual Report for year ending Sept., 30, 1900.

Henry V. Ahrbecker, Secretary Engineering Association N. S. W., Sydney, N. S. W., 10 vols., cloth, Proceedings of Engineering Association New South Wales, Vols. I, II, III, IV, V, VI, VII, VIII, IX, X, 1885–1895 inclusive.

Mr. Geo. F. Stone, Secretary Chicago Board of Trade, Chicago, 1 vol., cloth, Annual Report, Board of Trade, Chicago, 1899.

H. W. Thomlinson, Architect, Chicago, 1 pamphlet, Annual of the Chicago Architectural Club, 13th Annual Exhibition, 1900, "Art Institute"

D. L. Fulton, Allegheny, Pa., Secretary American Society Municipal Improvements, 1 pamphlet, Report 7th Annual Convention, American Society Municipal Improvements, Milwaukee, Wis., August, 1900.

Munn & Company, New York, 1 vol., cloth, Progress of Invention in 19th Century.

Addison J. McCune, State Engineer Colorado, 1 vol., cloth, Tenth Biennial Report, State Engineer Colorado, 1899–1900.

R. A. Shailer, Chicago, bundle of sundry pamphlets, nearly 16 vols. Journal Associated Engineering Societies, and nearly 5 vols. Journal W. S. E.

J. H. Warder, Chicago, 10 vols. unbound; Journal Franklin Institute, 1888–1892.

" " 4 vols. Transactions American Society Mechanical Engineers, Vol. IX–XI pamphlets, Vol. XVIII–XIX bound.

" " 1 bound vol. Transactions American Institute Mining Engineers, Vol. XIX, 1890–1891.

H. P. Boardman, Chicago, pamphlets, Journal of Geology, University of Chicago, parts of Vols II and V, Vols. III and IV.

E. E. R. Tratman, 4 pamphlets, Iowa Engineering Society Annual 1900, Indiana Engineering Society Proceedings 1900, Technograph No, 14, 1899–1900, Michigan Engineers 1900.

" " 1 vol., cloth, Baldwin Locomotive Works Catalogue, Narrow Gauge Locomotives.

" " 1 vol. bds. Administration Report Railways in India, 1898–1899.

Chief of U. S. Engineers, War Department, 4 vols., cloth, Report of Chief Engineers 1900, Pts. 5, 6, 7 and 8, completing reports for 1900.

J. R. Mann, M. C., 1 vol., Manual of Surveying Instructions for Survey of Public Lands.

Jones & Laughlins, Pittsburgh, 1 vol., leather, Standard Steel Construction, Book of Shapes, etc.

" " small vest-pocket book, leather, "Useful Information for Business Men, Mechanics, Engineers, etc."

Spon & Chamberlain, New York, 1 vol., cloth, Design and Construction of Oil Engines. By Goldingham.

J. B. Lippincott Co., Philadelphia, 1 vol., cloth, Oil Analysis. By Augustus H. Gill, Boston, Mass.

Philadelphia Book Co., Philadelphia, 1 vol., cloth, Artificial Ice Making and Refrigeration. By L. M. Schmidt.

Ossian Guthrie, Chicago, 1 vol., cloth, Kentucky Geological Survey, Jackson Purchase Region, 1888.

" " 8 pamphlets, 8 numbers Journal Associated Engineering Societies, Philadelphia.

" " 2 pamphlets, Proceedings Ontario Land Surveyors, 1894, 1897.

Brooklyn Engineers' Clubs, Brooklyn, N. Y., 1 vol., cloth, Proceedings of Club, Vol. IV, 1900.

U. S. Interstate Commerce Commission, 1 vol., cloth, 14th Annual Report December 24th, 1900.

U. S. Department Agriculture, Bulletin No. 18, 1 pamphlet, "Our Trade with Japan, China and Hongkong, 1889-1899."

Marcus Barker, Secretary Board on Geographic Names U. S., 2 vols., cloth, 1st and Second Report U. S. Board on Geographic Names.

Board of Health, New York, N. Y., 3 vols., boards, Annual Reports Board of Health 1897, 1898, 1899.

J. H. Warder, Chicago, 1 vol., cloth, Illinois State Board of Health, "Sanitary Investigation Illinois River and Tributaries, 1900."

Osborn Engineering Co., Cleveland, Ohio, 1 pamphlet, Abolishment of Grade Crossings, Report Special Committee, December 18, 1900.

Pacific Coast Ry. Club, San Francisco, Cal., 1 pamphlet, Official Proceedings Pacific Coast Ry. Club, March 16, 1901, Vol. II, No. 11.

Michigan State Agricultural College, Bulletin 186, December, 1900, 1 pamphlet; 1st Report Upper Peninsula Experiment Station.

Edson Manufacturing Co., Boston, Mass., 1 pamphlet, Catalogue of Pumps, Tools, Winches, Capstans, etc.

J. T. Ryerson & Son, Chicago, 1 pamphlet, "Boilers," Technical Library No. 4; Trade Catalogue.

T. W. Snow, Chicago, pamphlet, Catalogue Otto Gas Engine Works.

J. H. Warder, 1 vol., cloth, "Roads and Railroads." By Gillespie.

" 1 vol., cloth, Unwin's "Iron Bridges and Roofs."

" G. M. Bond on "Standards of Length and Their Practical Applications".

BOOK NOTES.

Sewerage: The Designing, Construction and Maintenance of Sewerage Systems. By A. Prescott Folwell, M.Am.Soc.C.E. New York: John Wiley & Sons. Cloth, 6x9 inches; pp., 372; 24 tables and 48 illustrations. Price, $3 00,

Mr. Folwell has furnished a very valuable work on practical construction, that portion of his book treating of this subject being of unusual value and interest.

The engineer in charge of work who encounters for the first time wet or difficult trenches will find relief from many anxieties in a careful perusal of the very full and interesting chapter on this subject. Nor does one often find better practical hints and suggestions than are given for difficult work in quicksand.

The information here given is notably from one who has experienced the difficulties whereof he speaks, and who has been alive to valuable suggestions from every quarter which he has assimilated with his own experience.

Equally valuable are the general hints and suggestions about all ordinary forms of construction, including the chapter on detailed plans and specifications, the latter being interlined with comments, in italics, which are excellent, particularly those with reference to back filling and ramming,

That portion of Mr. Folwell's work covering the problems of design are a good general restatement of recent practice, though in many cases it would have been desirable to give more liberally the authorities quoted and data used. Perhaps space prevented.

Thus, for instance, the statement on page 75: "It has been found in practice than an actual velocity of 1½ feet per second will ordinarily suffice to prevent deposits where house-sewage alone is admitted," needs both qualifications and elaborations, and even then would probably be questioned by some sanitary engineers.

The very good workable table of velocity and discharge for circular sewers could have been profitably supplemented by a similar table of egg-shaped sewers.

Not much light is thrown upon the subject of sewage disposal. The author expressly disclaims the intention of elaborating this subject; but even the outline given might, perhaps, have been boldly omitted and the space used to greater advantage otherwise.

A good many tables of sewage gaugings are compiled, but nearly all relate to normal flow, and hence are valuable only in designing the separate system sewers. At present there is, perhaps, no one point where more light is needed in sewer design than actual data of maximum run-off for storm water.

There is reason to believe a very wide difference of practice will be found in this country, not only as between different cities, but between different sections of the same city.

A large number of actual examples of rain-fall and run-off on sewer districts, accompanied by full data as to area, density of population, slope of surface, amount of pavement and roof area, and especially character of soil as to permiability and impermiability, will do more to place the work of designing combined sewers on a scientific basis than any other one thing at the present time

Engineers have not been in the habit of placing such data on record except in isolated cases, but there is reason to believe there is a large amount of it to be had could it be brought to light.

Taken as a whole, Mr. Folwell's book is helpful and valuable, especially to the young engineer.

The science of sanitary engineering is growing so fast that it is almost impossible any longer to cover the whole field thoroughly within the limits of one book, but doubtless a judicious outline from an author of recognized standing, with more or less fullness, where fullness is most important, makes a book which is more practical for the worker in this field than a more elaborate treatise might be.

A.

Sewer Design. By H. N. Ogden, C. E., Asst. Prof. of Civil Engineering, Cornell University. New York: John Wiley & Sons. Cloth, 5x7½ inches; 234 pages, 23 illustrations, 31 diagrams, 25 tables. Price, $2.00.

It is a comfort, now and then, to take up a book which does not attempt to cover more ground than can be thoroughly and properly dealt with.

Prof. Ogden's hand-book on sewer design has the excellent quality that it treats well the ground its title covers. The work is primarily intended for students, being derived from the writer's regular course of lectures; but it may be profitably placed in the library of every expert on sewer design, being well up to date in its information, and presenting in an orderly and logical arrangement all that is valuable or interesting in recent sanitary discussion of this subject. It is especially full of observed cases and collected data.

The writer begins with the subject of combined and separate systems, showing what is even yet not very generally admitted, that local conditions nearly always determine the selection of the system to be used, and even at times demand a combination of the two systems in the same locality. Sewer engineers who have acquired their experience with either one or the other systems, and thereby become partial to that with which they are most familiar, are apt to be unconscious of the fact that there is no longer any controversy as between the relative merits of the combined and separate system, but that the selection between them is a test of the broad-minded education of the designing engineer.

The chapter on "The proportion of rainfall reaching the sewers," and "Relation of density to percentage," are perhaps as valuable as any in the book, in that they bring out quite clearly the inherent difficulties of correctly proportioning storm water sewers where data is so deficient and factors so numerous and variable.

The discussion of this subject in the JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS, published since the date of Prof. Ogden's first edition, has also brought out the wide variation in practice found in different localities. Perhaps it is safe to say that nine-tenths of sewer design is for suburban districts, or, at least, urban districts, not largely paved or roofed, or likely to be. The wonderful increase in rapid transit facility in the last decade almost assures the prevalence in the future of less crowded urban conditions outside the radius of business centers than has prevailed in the past. Just what allowance should be made for these conditions is one of the problems of the time. It is evident that with more thinly settled districts wider variations of run-off will obtain in different localities, due to the increasing influence of unpaved soils.

Interesting and valuable chapters on "Population," "Ground Water," "Formula," have been compiled with all of the best recent data. A valuable list of diagrams is found in chapter 13, and the use of flush tanks has received especial attention, and new information has been obtained by inquiry among engineers where they are in use.

The volume is liberally supplied with plates and cuts and well indexed, and is a distinct addition to the resources of the working sanitary engineer. A.

The Scientific American Cyclopedia of Receipts, Notes and Queries. Edited by A. A. Hopkins. Published by Munn & Co., New York, 1901; 15th edition; 6x9 inches, 734 pages, cloth bound. Price, $5.00.

This book is largely compiled from "Notes and Queries" and "Correspondence" from the *Scientific American*, and also from Cooley, Spon and other similar sources.

The present edition shows a commendable tendency to quote sources of authority.

While touching on a vast number of subjects relating to the useful arts, the following subjects, with the number of pages devoted to each, may be mentioned as of interest to the engineering profession:

Preservation of wood, 4; fire proofing, 3; paints, 5; varnishes, 14; lacquers, 4; enamels, 3; polishing, 11; oils, 6; lubricants, 3; inks, 19; hektographs, 1; photography, 30; microscopy, 10; boilers, 4; electro metallurgy, 12; welding, 2; tempering, 2; alloys, 13. C.

A Short Hand-Book of Oil Analysis. By Augustus H. Gill, Massachusetts Institute of Technology, Boston, Mass. J. B. Lippincott Co., Philadelphia. Second edition, revised, 1900; 16mo, cloth; 5x7½ inches, 143 pages. Price, $1.25.

This hand-book is well written, clear and concise in its statements, and is emphatically a "hand-book" for the student and analytical chemist.

It is divided into two parts. Part I treats on the physical and chemical tests of "Burning Oils," "Lubricating Oils," "Animal and Vegetable Oils" and "Methods for Examination of an Unknown Oil." The apparatus for determining the physical characteristics of oils, as "flash point," "viscosity," etc., are illustrated. In this connection the author does not highly endorse the use of friction machines to determine the value of an oil for lubrication, but references are given to descriptions of such machines as the "Ordway-Woodbury" machine, the "Thurston" machine and the "Beauchamp-Tower" machine, each of which has found favor among some operators for its own special class of work.

Part II treats of the derivation, description and examination of oils, under the heads of "Petrolium Products," "Vegetable Oils," "Animal Oils" and "Waxes."

Sub-heads relate to adulterations and their detection, and the uses for the several oils enumerated.

The appendix contains many reference tables and formula; also a list of reagents and the specifications for oils as issued by the Philadelphia & Reading R. R.

There is a good index to the book, and there are references on almost every page to the authorities for the writer's statements, or to more extended literature treating on the several subjects. W.

The Progress of Invention in the Nineteenth Century. By Edward W. Byrn, A. M. Munn & Co., New York.

Considering the wonderful strides made in invention in the past hundred years, one would think the author had taken upon himself a great task; but he has discharged it probably as well as could be done in a book of 470 pages. The scope of the volume is well set forth in the following quotation from the author's preface: "The work cannot claim the authority of a text-book, the fullness of a history, nor the exactness of a technical treatise. It is simply a cursory view of the century in the field of invention, intended to present the broader bird's-eye view of progress achieved."

The author has made free use of the Patent Office records, so the main facts, dates of inventions, etc., can probably be relied upon.

The first chapter is "The Perspective View"; the second, "Chronology of Leading Inventions of the Nineteenth Century." The succeeding chapters take up the different subjects more in detail. Chapters 3 to 9 inclusive treat of the various applications of electricity. Then several chapters are taken up with steam and its uses.

A few of the other typical chapter headings are: Printing; Vulcanized Rubber; Food and Drink; Medicine, Surgery and Sanitation; The Phonograph; The Roentgen or X-Rays; Civil Engineering; Metal Working; Ice Machines; Minor Inventions, and Patents of Principal Countries of the World.

There are thirty-five chapters in all

Naturally, specialists who expect to find much information in their lines will be more or less disappointed at certain omissions, but too much must not be expected. The descriptions of the most important inventions and appliances are usually good and clear, and the gradual development along certain lines, such as the electric telegraph, printing, etc , is described in a very interesting manner. The author has aimed to give the proper credit for inventions.

Take it altogether, the book affords very interesting and easy reading, and is well illustrated. The table of contents by chapters gives no page reference, and every page of the text is headed by the general title of the book instead of by the particular chapter heading; but this inconvenience is partly offset by a very good index at the end. H. P. B.

Public Water Supplies: Requirements, Resources and the Construction of Works. By F. E. Turneaure, C. E., and H. L. Russell, Ph. D., of the University of Wisconsin; with a chapter on Pumping Machinery, by D. W. Mead, C.E., M.W.S E. Octavo xiv., 746 pages, 231 figures. Cloth bound, $5 00. New York: John Wiley & Sons, 1901.

This latest candidate for the favor of engineers interested in this branch of their profession is divided into two parts. Part I treats of requirements and resources of public water works, and is subdivided into *quantity* of water required, with sources of supply, and *quality* of water supplies. These nine chapters treat on modern requirements for quantity and supply, rainfall, flow of streams, ground water, examination of water supplies, quality of water, and communicable diseases with water supplies, etc.

Part II relates to the construction of water works, subdivided into "Works for Collection of Water," "Works for the Purification of Water," and "Works for the Distribution of Water" This is the largest part of the book, consisting of over 500 pages distributed through nineteen chapters. Some of the heads of these are: Hydraulics, pertaining to the movement of water under different conditions; Intakes from River and Lake Supplies; Ground Water and its Collection, Reservoirs, Dams of Earth, Masonry, etc.; Objects of Purification, and Methods by Sedimentation, Filtration and Other Processes; Distribution of Water by Pipes, etc.; Conduits and Pipe-lines; Pumping Machinery; Reservoirs and Distributing Systems, and finally Operation and Maintenance.

The constant reference to further sources of information for the several topics treated, whether to other books or to the technical periodical literature, is a valuable feature of the book, giving it an encyclopedic character, and is introduced at the conclusion of almost every chapter.

The whole subject of public water supplies is handled in a broad and liberal-minded manner, and treats of the most recent and approved practices, at the same time containing much valuable information of a practical character. W.

The Design and Construction of Oil Engines, with full directions for erecting, testing, installing, running and repairing, including descriptions of American and English Kerosene oil engines. By A. H. Goldingham, M. E. Fully illustrated. Published by Spon & Chamberlain, 12 Cortlandt street, New York, 1900. 8vo, 196 pp. Cloth, $2.00.

The author states in his preface "that this work was written with the intention of supplying practical information regarding the kerosene or oil engine, and in response to frequent requests received to recommend such a book."

"While many works have been published on the subject of gas engines, some of which refer to or describe the working of the oil engine, no other book, it is believed, is devoted entirely to the oil engine in detail."

The author covers the ground very thoroughly in nine chapters. He also gives some valuable tables of tests of engines and the properties of sundry oils, besides numerous illustrations. The book is furnished with a full index. We can heartily recommend this work to those interested. J. H. B.

Argentine Republic: Ministry of Public Works; Bureau of Inspection, Navigation and Ports. Competitive designs for the construction and operation of a commercial port at Rosario City; preliminary documents; index to documents and analytical table. Buenos Aires: Lithographing, printing and binding establishment of William Kraft.

There seems to have been so many projects for the port of Rosario, on the Parana river, that an index became necessary. Mr. E L. Corthel, M. W. S. E was called in as consulting engineer to report on the plans submitted. O. C.

Argentine Republic: Ministry of Public Works; Bureau of Inspection, Navigation and Ports. Competitive presentation of projects for dredging plants. Antecedents—Decision of the General Commission on the proposals of the firms receiving awards; Werf, Conrad & Co. and Satre Fils Aine & Co. Buenos Aires: Lithographing, printing and binding works of William Kraft.

The preface states that the Government, being in need of the best dredging plants for the improvement of its rivers and harbors, invited competitive projects from the whole world. Five firms responded, and the book gives particulars of the two projects selected by the jury. O. C.

Principles and Practice of Artificial Ice Making and Refrigeration. Louis M. Schmidt, Ph.B. The Philadelphia Book Co., Philadelphia, Pa., 1900. 8vo, XIV.; 231 pages, 87 illustrations. Price, $2.50.

This treatise is divided into four parts, as follows:

Part I deals with the principles of the subject as historical, methods of generation, methods of application, ice making, capacity for refrigeration, piping for refrigeration, insulation, features of the ammonia compression system, of the absorption system, and of a compressed air refrigeration plant, the brine and special appliances.

Part II shows the practice by particular systems and apparatus, and the well known machines of Linde, De LaVergne, Fetherstone, Boyle and Eclipse are described. These use ammonia. There is also described the anhydrous sulphurous or ammonia system, the carbonic-anhydride system, the compressed air system, and the ammonia absorption system of F. Carré,

Part III relates to structural insulation to prevent absorption of heat, as recommended by well known manufacturers of refrigerating plants.

Part IV consists of various tables and data of value to the managers or operators of refrigerating plants.

The book is provided with a good index and is well illustrated, but it does not go into the thermo-dynamics of the subject of refrigeration. It is not too technical for the general reader. W.

TRADE PUBLICATIONS.

Railway Water Appliances. The Otto Gas Engine Works, 360 Dearborn street, Chicago, Ill.

This handsome new catalogue, just issued by this company, fully covers everything that can be required for railway service, from a complete water station to details and price lists of separate parts. It shows the many applications of power from gas and gasoline engines, among railroads at the present time, including some new and novel devices.

The catalogue contains much to interest railway engineers. The illustrations and press work are superior to most trade catalogues.

Boilers. Technical Library No. 4, issued by Jos. T. Ryerson & Sons, Chicago.

This little pamphlet treats especially of internally fired boilers supplied with corrugated furnaces. This class of boilers has many advantages and generally has shown a high efficiency. The illustrations are good, showing various forms of construction, and particularly the Morison suspension furnace. The book contains a partial list of those using this type of boiler and high commendation from some experienced steam engineers.

The catalogue of the Edson Manufacturing Company, Boston, Mass., relates to their well known diaphragm pumps, and to other lines of manufacture, which include appliances and fittings for marine work, as steering gear, wrenches, capstans, etc. Also street sweepers for one and two horses which have proved satisfactory by many years' use.

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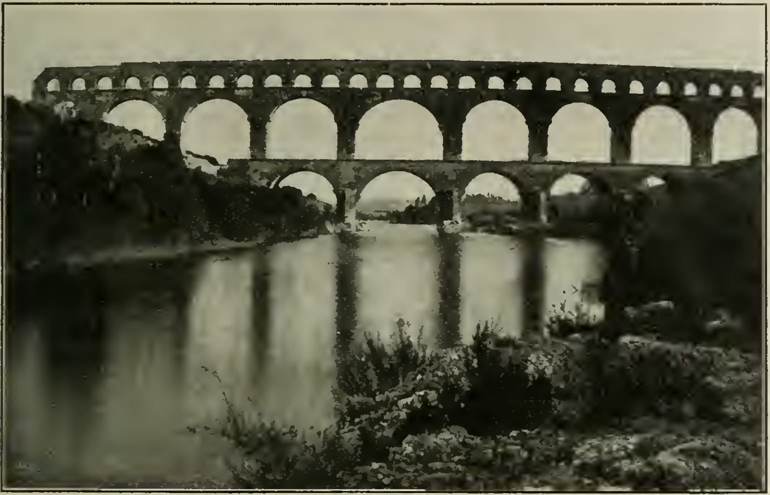


The Pont du Gard, near Nimes.

CXIX.

ENGINEERING PROBLEMS IN CEMENT MANUFACTURE.

By Prof. S. B. Newberry of Ohio.

Read April 17, 1901.

The production of Portland cement in the U. S. has increased in 11 years from 335,000 bbls. to 8,400,000 bbls., or more than 25 fold. At the present time Portland cement is produced at more than 50 factories, with an aggregate capital of over twenty million dollars, and the value of the product is not less than ten million dollars annually. In 1890 only 13 per cent of the Portland cement used in this country was of domestic manufacture; in 1900, with a total consumption more than four times as great as in 1890, only 21 per cent was imported.

The development of an industry in so short a time, under new conditions, to so great a magnitude, cannot fail to present some features worthy of study, and it may interest you, as practical engineers, to hear a brief account of the problems which American manufacturers have encountered, and how these have been and are to be solved.

First, a few words as to the nature of hydraulic materials.

Lime, as you know, is the basis of all hydraulic cements. A pure lime, however, will not harden under water, though it hardens in air by drying out and by superficial conversion into carbonate. It was known to the Romans that certain kinds of volcanic scoria, especially the "pozzuolana" found near Rome, and the "trass" from the Rhine, have the property of making lime *hydraulic* and greatly increasing its hardness. The Pantheon has walls 20 ft. in thickness and a dome 142 ft. in diameter made entirely of concrete, the basis of which is a cement composed of a mixture of pozzuolana and slaked lime. The Pont du Gard, near Nimes, a splendid aqueduct, is surmounted by a water conduit 6 ft. square in section, lined with this concrete, the inner surface of which is still hard and smooth after 1800 years of exposure to weather.

Some kinds of blast furnace slag have a similar power of making lime hydraulic, and "slag cements," consisting of granulated slag and slaked lime ground together, are manufactured to a considerable extent in this country and in Europe. In both cases the hardening is due to the gradual action of the silica of the pozzuolana or slag, already active on account of being combined with a certain amount of lime, on the added lime of the mixture.

It has long been known also that certain *impure* limes have strong hydraulic properties. Smeaton, engineer of the Eddystone lighthouse, discovered in 1756 that these hydraulic limes are those burned from limestone containing a considerable proportion of *clay*. If the amount of clay is small (10 to 20 per cent), the lime will slake after burning, and a slow-hardening *hydraulic lime* results. If the clay in the limestone is in larger proportion (30 to 40 per cent), the product will fuse at a high heat to a slag having no hydraulic properties, but if burned at a moderate heat and ground to powder, yields a light, quick-setting cement. This product, made by burning a limestone containing excess of clay, is the well known *natural cement* manufactured at Louisville, Milwaukee, Rosendale and elsewhere in the U. S. to a total amount of over eight million bbls. per year.

In the early part of the last century, Vicat, in France, carefully studied the relation of the clay contained in lime to their hydraulic properties, and found that an artificial mixture of carbonate of lime with a certain exact proportion of clay, usually about 25% of the total, gave a mixture which would bear an intense heat without fusing, and yield a hard, heavy clinker which on grinding gave a cement of extraordinary hardening properties. The manufacture of this product was begun in England in 1827 by Aspdin, who conducted the process with great secrecy, claiming the valuable properties of the material to be due to certain mysterious powders sprinkled into the kiln during the burning, the composition of which was known only to himself. The product was named *Portland cement*, from its resemblance in color to the Portland building stone. The manufacture rapidly extended in England and France, and was begun in Germany in 1852, and in the U. S. near Kalamazoo in 1874. The first successful production of Portland cement in this country was by the late Mr. D. O. Saylor, at Coplay, Pa., in 1878.

Hydraulic cements may then be divided into four groups as follows:

1st. Pozzuolana or slag cements, made by mixing volcanic scoria or granulated slag with slaked lime.

2d. Hydraulic lime, made by burning a limestone containing a small amount of clay, and slaking the product with water.

3d. Natural cement, made by burning at a moderate heat a limestone containing excess of clay and usually much magnesia, and grinding the product.

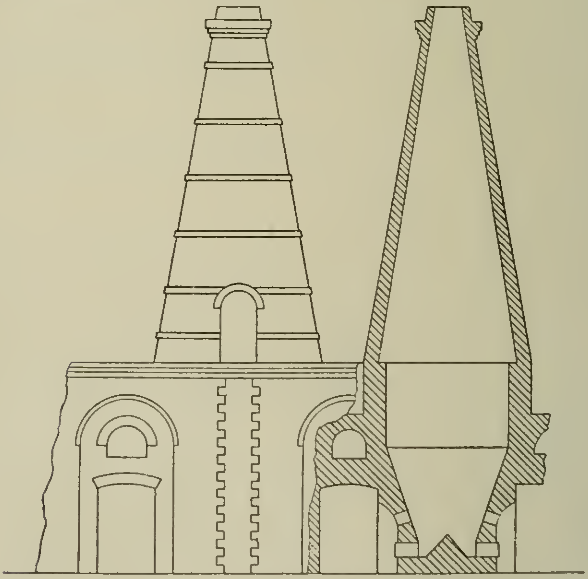
4th. Portland cement made from an artificial mixture of carbonate of lime (limestone, chalk or marl) with exactly the right proportion of clay, by burning at a high heat and grinding the resulting clinker to powder.

Of these four classes, Portland cement is generally agreed to be greatly superior to the others in strength, promptness in hardening, uniformity and durability.

Since the difference between Portland and natural cement consists only in exactness of proportions and degree of burning, it is obvious that no sharp dividing line between the two can be drawn. If a bed of limestone of uniform composition, containing exactly the right proportion of clay, could be found, Portland cement could be made from it by a simple burning and grinding. The allowable variation in the percentage of carbonate of lime in a Portland cement mixture does not, however, exceed one-half per cent. The probability of finding an extensive bed of material of uniform and exactly correct composition is therefore extremely slight. Many deposits of limestone containing clay are known, and some of these approximate to the composition required, but in all cases it is necessary to select the different strata and grind them together, generally with the addition of clay or pure limestone, to bring the mixture to proper proportions.

MATERIALS AND PROCESS.—For the manufacture of Portland cement we require, then, carbonate of lime and clay, either more or less perfectly mixed by nature as in the case of clay-limestones just described, or entirely separate. In England, chalk and clay are used; in Germany, limestone or marl and clay. In the U. S., an unlimited deposit of clay limestone is found in the Lehigh Valley region in Pennsylvania, and from this material, within a radius of 15 miles, with Bethlehem as its center, 80% of the domestic product is made. This limestone is mostly too low in lime, containing about 67 to 70% carbonate, and it is usually necessary to add about 20% of a nearly pure limestone to bring the composition up to the correct figure of 74 to 75% carbonate. Some of the mills in the Lehigh Valley region are of vast extent, and one of these, which produces 8,000 bbls. per day, is by far the largest in the world.

Limestone containing clay is also found near La Salle, Ill., and factories have lately been established at that point. In the central section of the country, marl, a soft, finely divided form of carbonate of lime, and clay are the materials employed. Pure limestone is used to a small extent, but is not a favorable material, owing to the high cost of pulverizing it to the fineness necessary to secure an intimate mixture with the clay.



Ordinary Kiln.

The first essentials to the production of a high grade cement are correct proportions of the ingredients and thorough mixing and fine grinding of the raw material. A variation of one-half per cent from the correct proportion of carbonate of lime will noticeably affect the product. If too high in lime, the cement will expand and crack; if too low, it will be quick-setting and lacking in strength. Either of these defects, or both at the same time, may result also from imperfect mixing and grinding of the raw material. Faulty character of cement may, in nine cases out of ten, be traced to carelessness in the first stage of the process.

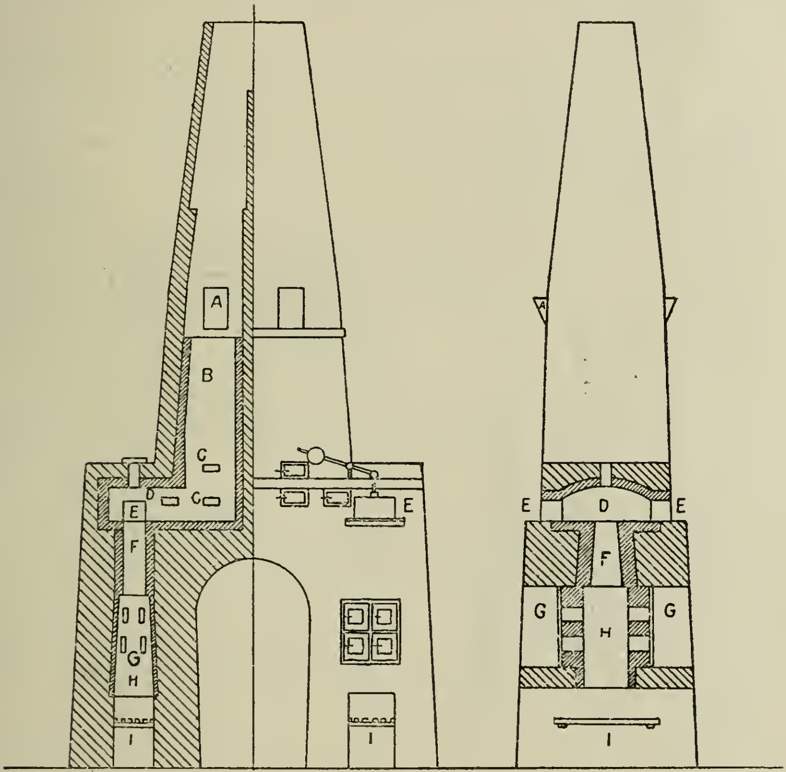
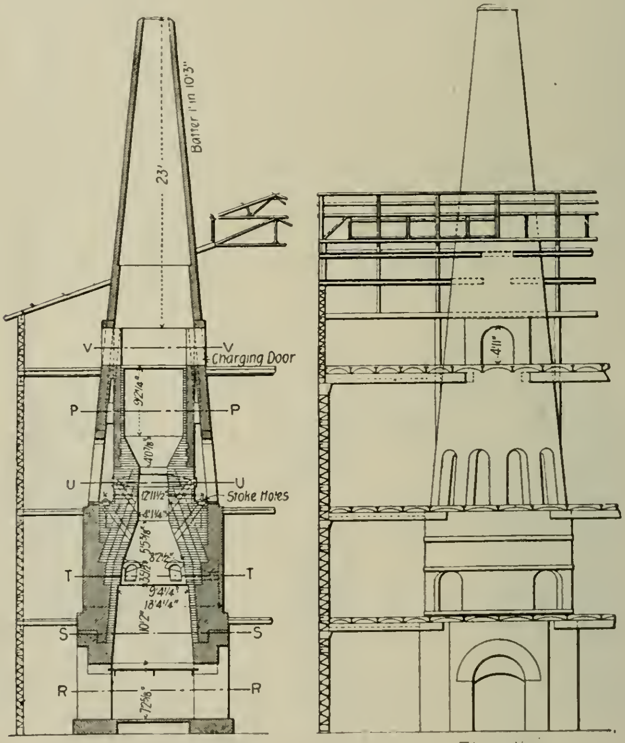


FIG V. DIETZCH KILN

A. Door for loading the raw meterial.
B. Heater.
C. Peep holes.
D. Horizontal channel uniting the heater and the crucible.
E. Doors for the introduction of the fuel.
F. Crucible.
G. Deep holes.
H. Cooling chambers.
I. Grates.

The burning of cement was originally done in small intermittent kilns, similar to lime-kilns. Continuous vertical kilns, in which the clinker is periodically drawn from the bottom, have been to some extent adopted, and in these two forms of vertical kiln, and the

Hoffman ring-kiln, practically all the cement of Europe is burned. These kilns are economical of fuel, requiring coke or coal to the amount of only 12 to 20% of the clinker obtained. In the Aalborg continuous kiln the cost of fuel is stated to be only 5 cents per bbl. of cement produced. The use of vertical kilns, however, necessitates the molding of the mixture into bricks, and drying these bricks on wagons in drying tunnels before burning. This involves great expense for labor and fuel and also adds materially to the cost of the plant.



Cross-Section through Kiln

Elevation

The Aalborg-Schofer Kiln.

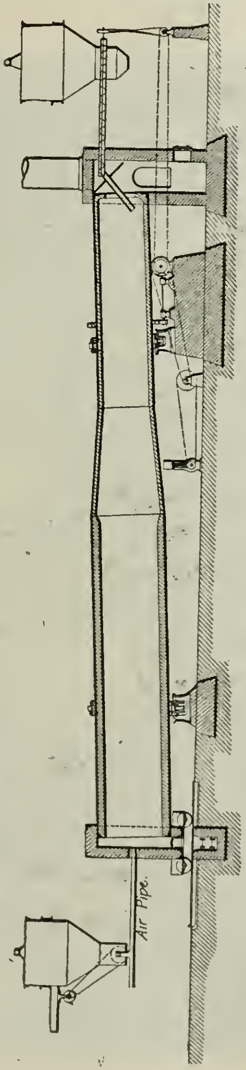
In 1868 Siemens, in England, patented the continuous burning of cement in a slightly inclined rotary cylinder. The same device, in combination with a gas producer, was again patented by Ransome in 1885. The plan was to do away with molding and drying the raw material in the form of bricks, and to introduce it continuously as a dry powder at the upper end of the cylinder, to be discharged as burned clinker at the lower end. Ransome's kiln was small and imperfect, the temperature obtained with producer gas was insufficient, and Ransome's experiments resulted unsatisfactorily and were abandoned.

The rotary process, with its promise of great economy of labor, soon, however, attracted the attention of American engineers. Experiments were undertaken at Coplay, Pa., by Navarro and by Whitaker about 1888, with the use of petroleum as fuel, and gave encouraging results. Rotary kilns of larger size were constructed, the necessary conditions of temperature and composition of the charge were determined, and it was soon demonstrated that well-burned rotary cement was superior in quality to that obtained from the old-fashioned vertical kilns. This improvement in quality is due to the quick burning and quick cooling, the chemical changes being checked at the point of maximum hydraulic properties. A further advance was made at Montezuma, N. Y., and at Sandusky, Ohio, in proving that good results may be obtained by introducing the raw material in the form of wet mud at the upper end of the rotary kiln. The burning and drying thus take place at one operation.

Petroleum was an excellent fuel for cement burning, but soon became too costly. An excellent substitute was found in finely powdered coal, blown into the kiln with a blast of air. The coal burns like a gas flame, giving no smoke and producing an intense heat.

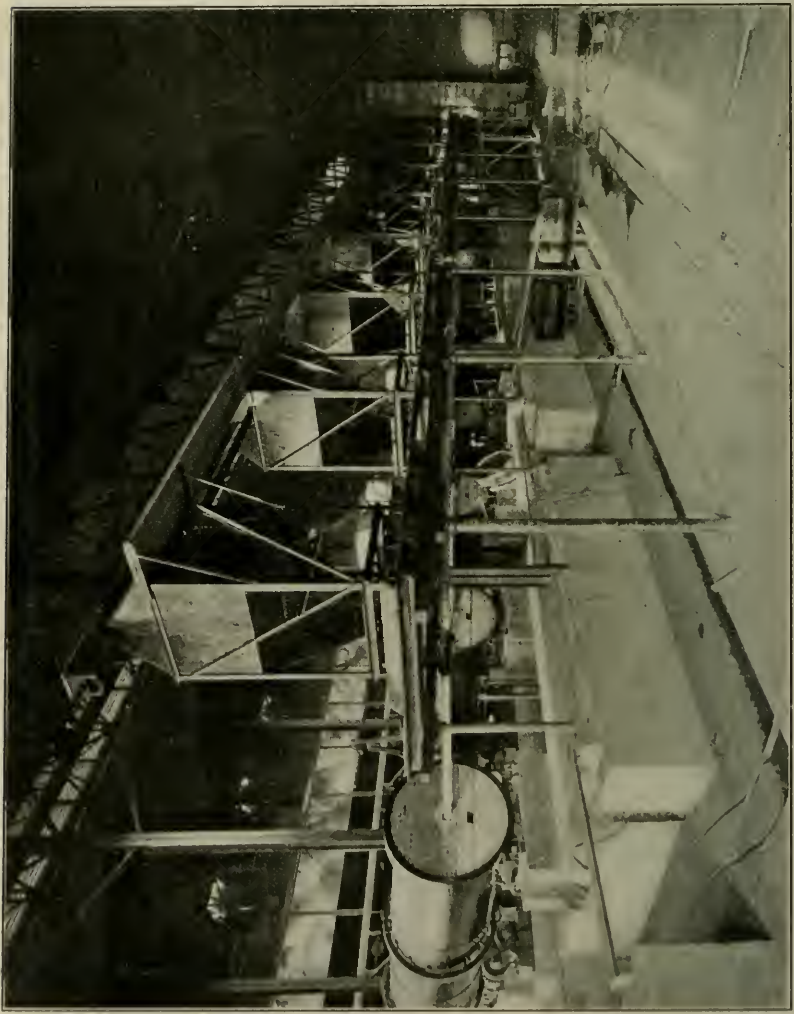
The use of the rotary kiln rapidly extended, and at the present time there are over 200 kilns of this type in operation in this country, with a total output of over six million barrels of Portland cement annually, or more than 75% of the total product. All new factories are equipped with rotaries, and many of the older factories hitherto using vertical kilns are adding rotary kilns to their equipment.

The construction and operation of the rotary kiln may be simply described as follows:



Sectional View of Rotary Kiln.

The kiln consists of a steel cylinder usually about six feet in diameter and 60 ft. long, lined with fire brick and mounted on rollers at a slight inclination. The kiln turns at the rate of one revolution in from one to two minutes. The raw material, in the form of wet mud or dry powder, is continuously fed in at the upper end; as it descends it becomes dry, then red hot, loses its carbon dioxide, reaches a nearly white heat in the lower third of the cylinder, and finally issues at the end in the form of small rounded pieces of hard black clinker. This when cooled and ground to powder forms the



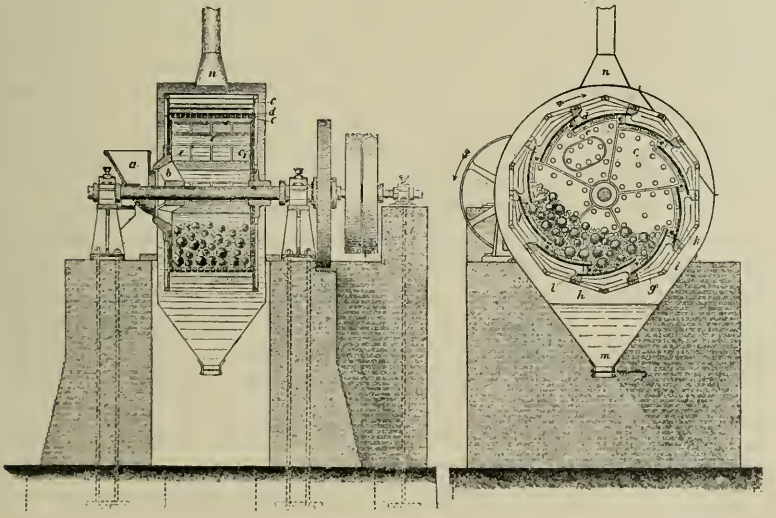
Battery of Rotary Kilns, Using Powdered Coal as Fuel.

Portland cement of commerce. The advantage of the rotary kiln, in economy of labor, is evident at a glance; since all molding, drying and handling of the raw material is done away with. Unfortunately, the rotary kiln is extravagant in fuel and cannot compare in this respect with the vertical kiln. The relative fuel consumption in kilns of various types, in per cent of clinker obtained, may be stated as follows:

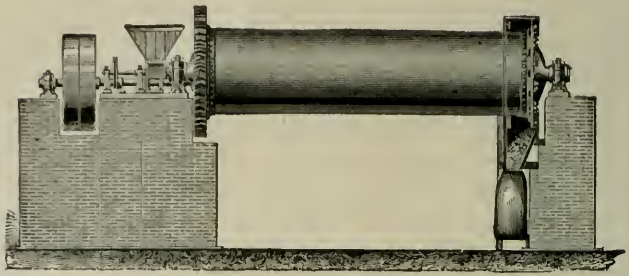
Intermittent vertical kilns, coke	20%
Continuous " " soft coal,	12%
Rotary kilns, dry material, " "	33%
" " wet " " "	40 to 50%

In this country, with labor costing twice as much and fuel one-half as much as in Germany, the slight additional fuel cost is insignificant in comparison with the saving in labor. In fact, it may safely be said that if it had not been for the rotary kiln, the Portland cement industry of the United States would to-day be of small importance.

This type of kiln is now attracting attention in Europe, and 32 rotary kilns have lately been installed by J. B. White & Bros. of England. In Germany these kilns have also been set up at two factories. There is good reason to believe that the fuel consumption in this type of kiln will be greatly reduced in the near future by the utilization of the heat now escaping from the stacks and carried off by the white-hot clinker. This is a problem worthy of the careful attention of American engineers. Up to the present time the de-



Ball Mill.



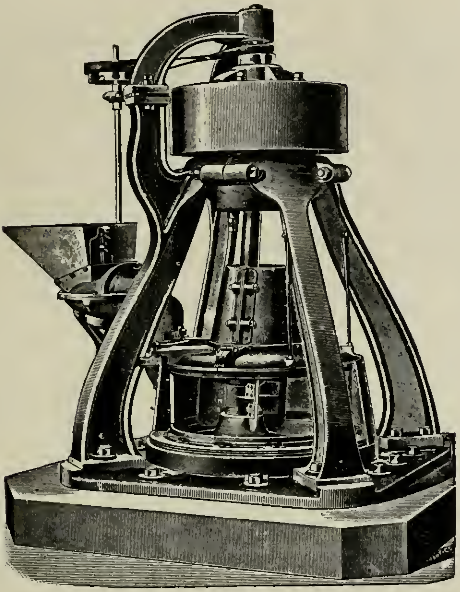
The Smidth Tube Mill.

mand for Portland cement has been so active that manufacturers have found it to pay better to increase the output rather than to study economy of manufacture. Now, however, the product has overtaken the demand, prices have fallen and competition is keen. It is a case of the "survival of the fittest," and the fittest will be those who narrowly watch the process and practice economy in every detail.

The grinding of the cement clinker is an operation requiring heavy machinery and involving high cost for repairs. Buhr stones, similar to those used in flour mills, were formerly used, but proved very expensive to maintain. Of late years, ball and tube mills, or Griffin mills, have been almost universally employed. The ball mill is a revolving drum partly filled with forged steel balls and provided with screens on the periphery. In this the clinker is reduced to the fineness of coarse sand, and is then ready for further reduction in the tube mill. The latter is a revolving cylinder, usually 22 feet long and 5 feet in diameter, lined with porcelain or hard iron, and nearly one-half filled with round flint pebbles. The product of the ball mills is continuously fed into it at one end and discharged at the other end, ground to a degree of fineness which may be regulated by the rapidity of the feed.

The *Griffin mill* is something like a mortar and pestle on a colossal scale. A slight tapering roll head, weighing 400 lbs., attached to a vertical shaft hanging from a ball joint, revolves at high speed against the inside face of a steel ring, 30 inches in diameter and 6 inches high. Plows on the bottom of the roll-head throw the clinker up against the ring, and the fine dust passes out through screens above the ring. The output of the Griffin is very large for the power required, and fully compensates for the relatively high cost of repairs.

The quality of Portland cement depends largely on the fineness of grinding. Foreign cements are generally ground to such a point that from 85 to 90 per cent passes a sieve of 100 meshes to



The Griffin Mill.

the linear inch. American Portlands generally show 90 to 95 per cent through No. 100. Fine grinding lowers the neat tests and increases the sand tests. In fact, cement may be so finely ground that it will show higher results with three parts sand than it will show when tested neat. There is, of course, a point beyond which it is not economical to carry the fine pulverizing of cement, since the same practical result can be accomplished by using slightly richer mixtures on the work.

As to the quality of the Portland cement now produced in this country, no better testimonial can be found than that given in the reports of Mr. Richard L. Humphrey, Cement Inspector of the City of Philadelphia, for the years 1896 to 1899.* These reports include tables showing graphically the results obtained with all cements tested in the Philadelphia city laboratory in the years mentioned. These tables show that the average of all American cements, both neat and with sand, is distinctly higher than that of the English or German. This evidence, with numerous similar records obtained by government and private engineers, warrants the claim that there is to-day no Portland cement made in any foreign country that is equal in quality to the product of the leading American factories.

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* Proceedings of the Engineers' Club of Philadelphia, 1896, Vol. 13, page 184. 1899, Vol. 16, page 193.

DISCUSSION.

Mr. T. T. Johnston—I came here this evening to listen rather than to talk. The talk given to us by Mr. Newberry has certainly been interesting and quite instructive in a great many respects. I had the pleasure, I believe, three or four years ago, of meeting Mr. Newberry's brother at the Alpha Mills in New Jersey and had a very interesting talk with him, and this evening has reminded me of that occasion very strongly. If not imposing too much on Mr. Newberry, I would like to ask a few questions. One is as to the particular effect of the addition of small quantities of gypsum in the manufacture of Portland cement, what good it does or what harm it does.

Mr. Newberry—Portland cement has a tendency to become quick-setting at the start unless the lime is very high, and all over the world it has been the practice for a great many years to add a little gypsum for the purpose of slowing the setting. That addition is expressly allowed for by the German Government, and the specifications of the Ministry of Public Works permit the addition of gypsum up to 2%.

I have made tests of cement with no gypsum, 2%, 5%, 10% and 20%, extending over two years, and I could see no bad results with less than 10%. For my part I cannot see any harm in the addition of gypsum up to 2%.

Mr. Johnston—As I understand Mr. Newberry, the use of gypsum is for the purpose of modifying the early setting properties of the cement.

Another question I wish to bring up is in regard to the irregularity of the setting. We find quite a number of cements that will set before you can make a briquet, and the time of setting will vary from that up to three or four hours. In one or two instances I have found that the rate of setting will change in the time the cement is shipped from one point to another, and in two days or several weeks has changed from rapid to slow setting cement. This has led to more or less confusion as to whether or not the cement was good, making it seem doubtful. This, however, may be a question that bears more particularly upon the subject of testing of cements.

Last fall I had occasion to buy some cement—1200 or 1500 barrels—to be used in the construction of a dam, and consequently I had to be somewhat particular about the kind of cement that was to go into it. I had a man to go to a cement mill and collect some samples. They were sent to Chicago and tested in a laboratory of good standing, where I watched the testing. They were tested for fineness, setting, strength, sand test, the ordinary boiling test, etc., and they showed up all right in the boiling test the next day. To all appearances that cement was all right excepting that the seven day test ran higher than it ought to for that particular cement. At the end of seven days the briquets were boiled and some of them swelled so as to be nearly ¼ inch longer than the others. How can we investigate and test a cement and get rid of a difficulty of that kind?

Mr. Newberry It does appear as though our boiling test was not adequate, and does not entirely reveal the defects of the cement, and still I do not think anyone will claim that if the boiling test turns out badly the cement will be sound. I am surprised that any engineers should reject the boiling test, as many do, while manufacturers use it constantly, and without the use of the boiling test a sound Portland cement could not regularly be made. I certainly cannot account for such a result as this. Did you say that these samples were both taken from the same lot of cement—that is, taken out of the same car?

Mr. Johnston—A lot of several cars showed the same result.

Mr. Newberry—I would say that in all probability the principal fault of cement showing such things as that is light burned. You cannot positively state that the particular sample from which that briquet was made was subjected to the boiling test?

Mr. Johnston—No; a boiling test was not made of all the samples.

Mr. Newberry—I should be very sorry indeed to lose confidence in the boiling test, and am convinced that the differences shown in the tests were due to differences in the samples tested.

Mr. Johnston—Once before, in testing some cements several years ago, I found some four or five cases of this kind in the pats of a certain lot after about three months. That was the only fault to find with that certain lot of cement, and we made tests running over a considerable period.

One case in testing that came up within a year in a well known cement showed normal in every respect except sand-bearing qualities. A great deal of that cement had been tested in the laboratory already mentioned. The young men who were making the briquets were entirely competent and their product was regular. I have never been able to satisfy myself as to why several car loads of this cement should depart radically from the ordinary habits of this cement in this one particular.

One other question I would like to ask. It is one I have heard raised frequently but I have never had it satisfactorily explained; that is, what would be the effect of using lime water in the mixture of mortars in contrast with using the water in ordinary use?

Mr. Newberry—When water acts on cement it dissolves out a small amount of lime, becoming lime-water. As water at ordinary temperatures dissolves only one-seventh of one per cent of lime (0.14%), the quantity taken up from the cement is very minute. It therefore makes practically no difference whether soft water or lime-water is used. If water percolates continuously, however, through porous mixtures of cement and sand, it will in time dissolve so much lime out of the cement as to weaken its cohesion. In testing cements, therefore, the briquets, especially sand briquets, should not be kept in running water.

Mr. Boardman—In renewing the water and making it fresh at short intervals it continues to dissolve the lime out of the briquets. Does it injure the briquet by dissolving the lime?

Mr. Newberry—It certainly does. It is better to leave the same water in the tanks or enough to keep it above the briquet.

Mr. Boardman—A great deal of laboratory practice has been to renew the water once a week; that is, draw off all the old water that has been saturated with alkali and renew with fresh water.

Mr. Newberry—It cannot do any harm to renew the water once a week; but where you have the sand briquets, "1 to 3," they are certainly liable to injury from running water, and it may in time dissolve the cement from the briquets. If concrete is made dense so the water cannot penetrate, it cannot do any harm.

Mr. McHarg—In regard to the manufacture, I would ask whether the coal which is used in burning is necessarily of a high grade, or whether the Indiana and perhaps the better grades of Illinois coals are proper to use? Do you use a high grade, such as the Pittsburgh or Ohio coals, or do you use the Indiana?

Mr. Newberry—To answer that I would say that, in order to burn the coal in the form of dust, it has to be ground fine, and previous to the grinding it has to be dried. The Indiana and Illinois coals are all very wet, and the same is true of the Ohio coals. The Jackson (Ohio) coal contains about 8% of water, and I think some of the Illinois coals run as high as 10 and 12%, and it would be difficult to dry these.

Mr. McHarg—As a matter of fact you use the Pittsburgh or West Virginia coal simply on account of the ease in drying?

Mr. Newberry—Yes.

Mr. Rice—How fine is the coal ground?

Mr. Newberry—The coal is ground to such fineness that at least 90% will pass through a 100-mesh sieve; about the same fineness as cement.

Mr. Bergquist—I would like to know your idea of the reason why the neat cement briquets generally at a certain time show a decrease of tensile strength and then increases again, while the cement tested with sand generally shows more constant increase of strength. Some time ago I saw the results of a series of tests extending over five years, from a dozen or more different brands of Portland cement, and invariably every one showed a drop in strength in neat tests somewhere between three months to one year.

Mr. Newberry—I cannot give any explanation for that; it may be that after hardening the cement crystallizes, and that the crystallization is accompanied by considerable expansion. The briquet may be very strong, but yet may be very easily ruptured and may become exceedingly brittle in hardening. That is the way I explain the falling off in strength in neat briquets, even with the best cement; but as for regaining its strength, I cannot give any explanation of that. It still remains to be investigated.

Mr. Thomas—I would like to ask if salt or sea water has any bad effect in the mixing of cement.

Mr. Newberry—It has much more tendency to produce expansion. One of the most useful methods is to heat pats of cement in hot solution of salt and calcium chloride, or artificial sea water. This subject is being investigated by the German Cement Makers' Association. They are conducting a large number, experiments on the action of sea water, but they have not as yet reported results.

Mr. Thomas—My reason for asking that question is this, that on one of the jobs on which I was working I was forbidden to use salt water, and fresh water was very difficult to obtain, notwithstanding the fact that the gravel entering into the concrete was taken from the seashore and also the sand.

Mr. Newberry—The salt has a tendency to make cement quick setting.

Mr. Thomas—Would you consider the use of salt in concretes in cold weather injurious to the cement?

Mr. Newberry—No, I do not think it is at all injurious to the cement, as it is constantly used, and I think successfully, in the preparation of mortar for use in cold weather, by the addition of a certain amount of salt to the water.

Mr. Finley—I have had occasion to use cement and water at a temperature of say 30 degrees below zero; we used salt; that was four years ago, and I have never found the slightest bad effect from it.

Mr. Thomas—That was also my experience, but I have asked in regard to this a number of times and never got a satisfactory reply.

Mr. Reichman—I would like to ask whether an excessive amount of water put in a concrete mixture has any effect on the change of volume when it sets.

Mr. Newberry—I think I ought to ask some experienced engineer to answer that question. I should suppose that excessive water would tend to increase the shrinkage. You, perhaps, are familiar with a work published by the C. M. & St. P. Ry. on this subject. That paper was certainly very striking in its statement to the effect that concrete was better if made wet than if made dry.*

Mr. Reichman—That article was written with reference to a small volume, and I wished to inquire with reference to a larger volume.

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* Journal Western Society Engineers, Vol. 5, page 488.

Chairman—On the contrary, the results of these tests at the Washington University show they get better results from the dry mixture. I have always been of the opinion that the wet mixtures would not leave as solid a body of concrete as a dryer mixture; that there would be more danger of the formation of water through it than with a dryer mixture.

Mr. Boardman—What would you say of cement that showed 900 pounds seven day and then lost in strength later to a marked degree, and yet stood all steam and boiling tests, even boiling the pieces of briquet after breaking?

Mr. Newberry—I should say that if the loss of strength was in the neat tests only, the cement was absolutely sound and trustworthy. I, perhaps, might have mentioned, in talking of the processes, that remarkably high tensile strength at short periods is characteristic of cements made from materials which are exceedingly finely ground. The cement is extremely active in its hardening properties; that is a quality that cannot be avoided, and if there is any falling off in strength of the neat briquet, it seems to me that the cause must be found in some phenomenon connected with internal strains and crystallization.

Mr. Boardman—I should like to ask a few questions about uniformity of materials used in the manufacture of Portland cements. What is the method and frequency of taking samples for analysis of the quarry rock, clay, etc., before the mixing? If you take a sample, for instance, of every ton of rock before the clay is added, can you be sure of the exact quantities of lime, alumina, etc., contained, unless the different analyses check almost exactly?

Also, do you make analyses after mixing the raw ingredients to assure yourself of uniform mixing of raw materials before burning?

Many engineers have found by tests that the product they get is often very far from uniform, as illustrated by Mr. Johnston's boiling of briquettes, one of which swelled materially, while others from the same car were O. K. As wide variations are often noticed, not only in boiling, but in time of setting, and tensile strength of different parts of the same carload lots.

This being the case, how can manufacturers consistently claim uniformity of quantities and mixing of raw materials within one-half of 1%? If engineers could be assured that the best machine concrete mixers gave concrete uniform in relative quantities of cement, sand and stone, within five (5) per cent in different parts of the structure, I think they would be well satisfied. Of course, the two kinds of mixing are quite different; but in face of the facts as to irregularity of product often received, I do not see how claims of uniformity within such very close limits can be supported.

Mr. Newberry—Correct proportions and thoroughness of mixing are the first essentials of cement manufacture. Many American manufacturers are careless or unsuccessful in this respect, and decided variations in quality of product often occur. In the Lehigh Valley region, where natural cement rock is used, the chemist gets his samples of the next day's raw material from the mud washed out of the holes drilled for blasting, and is thus able to determine just what proportion of limestone must be added. Chemists vary greatly in their skill and ingenuity in this work. At factories where marl is used, this should be stored in tanks of sufficient size to allow the chemist to make a full analysis before the material is used, and thus to determine just how many lbs. of clay each cubic yard of marl should receive. If the right proportions are used, there should be no trouble about the thoroughness of the *mixing*, as the various operations of grinding in ball mills and tube mills, and the handling of the material in conveyors or pumps, all tend to bring it into the condition of a uniform mixture. At a recent meeting of the Association of German Portland Cement Manufacturers, the representative of the Stettin factory stated that during the preceding year the percentage of carbonate of lime in the raw cement mixture had only twice reached a point one-half per cent lower, and once one-fourth per cent higher than the normal. The records of the factories with which I am connected show an almost equal uniformity. This is the goal toward which American manufacturers should strive. With a properly arranged plant and careful supervision, it is undoubtedly possible to keep the composition of the mixture within one-half per cent of the normal.

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CXX.

A SIMPLE METHOD OF DETERMINING CONDITION OF COMBUSTION, WITH SUGGESTIONS ON WORKING FURNACES.

By A. Bement, M. W. S. E.

Presented to the Society May 1, 1901.

It is not the object of this paper to discuss the usual methods and means of combustion gas analysis, but rather to invite attention to a simple method especially suited to the requirements of regular work.

Usual analytical methods, while valuable in much experimental work, are not well adapted to boiler and furnace room conditions and requirements, because of the delicacy of the instruments, the time consumed in the work, and the skill required.

The instruments used in the work submitted as illustrating the special features here present, are designed to determine the percentage by volume of carbon dioxide in combustion gases—one by chemical absorption, the other by gravimetric determination. The first, known as Arndt's CO_2 absorber, is operated by introducing the gases from the flue by means of a small rubber hand pump, accompanied by a simple manipulation for exposure to the reagent; its maximum speed of operation is a determination at 30-second intervals. The second instrument is known as Arndt's gas weighing econometer, in which a moving stream of gas is weighed by a delicate balance enclosed in an iron case with a plate glass front, the percentages being indicated by a pointer moving over a graduated scale. This instrument is continuous and automatic in its operation, and is usually mounted at a convenient location on the wall, pipes being led from the different furnaces to it. The different plotted curves of CO_2 shown in the various diagrams used for illustration, and designated "analysis," are from the former instrument, while those designated from "econometer" are from the weighing machine.

In all usual analytical methods working with products of combustion, carbon dioxide or CO_2, which is its chemical term, is first determined, and as the work proceeds to other constituents the difficulties and time required advances. In view of this, and to the fact that CO_2 is the first and most important constituent of combustion gases, it is proposed to employ its volume as affording evidence concerning air supply; and also the condition known as incomplete combustion, or the oxidation of carbon to carbon monoxide; CO, as designated chemically. This would be accomplished by a knowledge of the volume of CO_2, taken in connection with observed conditions and methods of working the furnace.

As an initial illustration leading to the point in view, the combustion process will be the best examined from the standpoint of the air supply. It is apparent that air in proportion of 21 parts oxygen and 79 parts nitrogen will flow into the furnace, and it is the 21 parts of oxygen only that are to be considered, because the nitrogen, as far as the subject under discussion is concerned, is an inert gas and is treated only as a residue. Of the 21 parts or per cents of oxygen, from one to three combines with hydrogen, forming H_2O, a gas at furnace temperature, but a liquid or water at the temperature at which analysis would be made; for this and other reasons the H_2O is not considered. The amounts of oxygen going to H_2O, as here stated, are not given as being accurate, but approximate for purpose of illustration; the smaller amount would be usual with anthracite as fuel, while a bituminous coal high in fixed carbon combustible, would use the medium amount, and a bituminous coal low in fixed carbon, but with an equal weight of hydrogen, would use the greater volume of oxygen. There would then be left for use of the carbon from 18 to 20 parts of oxygen. The specific volume of carbon dioxide being the same as that of oxygen, it will be noted that this is a feature of great convenience, as simplifying the problem. It may be said, for illustration, that the carbon saturates the oxygen, and while not increasing the volume, does increase the weight of each part of oxygen saturated by about 50 per cent. This will be shown by the following compositions:

Entering, oxygen	21	volumes.
Entering, nitrogen	79	"
	100	
Gases leaving, nitrogen	79	volumes.
Gases leaving, carbon dioxide	10	"
Gases leaving, oxygen	9	"
Balance lost to hydrogen	2	"
	100	volumes.

Or another example which would be a theoretical condition:

Gases leaving, nitrogen	79	volumes.
Gases leaving, carbon dioxide	19	"
Balance lost to hydrogen	2	"
	100	volumes.

In the analysis, however, as the H_2O does not enter into account, the relations are somewhat changed. For example, presented in the usual way and with combustion complete:

Carbon dioxide	10.0	volumes.
Oxygen	9.0	"
Carbon monoxide	0.0	"
Nitrogen (residue)	81.0	"
	100.0	

Or with incomplete combustion:

Carbon dioxide	9.0	volumes.
Oxygen	8.0	"
Carbon monoxide	2.0	"
Nitrogen (residue)	81.0	"
	100.0	volumes.

It will be apparent that the possible attainment in percentage of CO_2 will be limited by the available percentage of oxygen, which may be from 18 to 20 per cent of the volume. For a proper presentation of the matter this should be designated as that of the theoretical point of CO_2.

The object of the usual analysis is more particularly to determine the two carbon oxides, but the conditions imposed by the chemical process requires, that CO_2 be first determined, and oxygen next in order, before that for CO can be attempted; this is because the reagents used not only absorbs the constituent for which it is intended, but those preceding as well. For this reason these constituents must be removed in the order stated.

If CO_2 was the only carbon oxide the problem would be very simple, because then its determination would be the only one necessary, and its amount compared to the theoretical would afford a true measure of the condition of combustion. But as carbon will also be oxidized to CO, a valuable compound in a gas producer, but an objectionable one in a heating furnace, the result is that this condition may and does introduce a complication, because CO_2 in its relative volume may be influenced by the presence of air, which is shown in analysis by the measurement of its oxygen; or it may be influenced by formation of CO, each causing CO_2 to be relatively less; therefore, a knowledge of the volume of CO_2 only, gives no evidence whether conditions are influenced by excess of air or by incomplete combustion. The leading object of this paper is to call attention to means whereby this difficulty may be overcome by comparing prevailing conditions with the volume of CO_2.

The following examples are presented for purpose of illustration in this connection:

Free open fire and strong draft:

Carbon dioxide	3.4
Oxygen	15.6
Carbon monoxide	0.0

Good even condition of fire, with properly adjusted air supply:

Carbon dioxide	14.1
Oxygen	4.9
Carbon monoxide	0.0

With an accumulation of ash and clinker on the grates:

Carbon dioxide	8.5
Oxygen	7.2
Carbon monoxide	3.4

With a large amount of fuel added at one coaling:

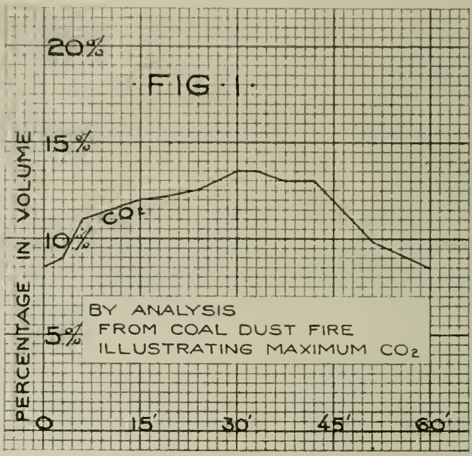
Carbon dioxide	10.4
Oxygen	5.7
Carbon monoxide	2.9

If the CO2 is compared with the prevailing conditions, the reason for its amount is apparent; for example, if the CO2 increases with reduced air supply, or increased coal supply, it would show that the air had been in excess of requirements; or if the CO2 increased after increased air, it would show that incomplete combustion had prevailed.

Insufficient air supply has usually been considered as the cause of the formation of CO, and in this connection the following compositions will be of interest:

	1	2
Carbon dioxide	13.6	11.1
Oxygen	5.6	7.6
Carbon monoxide	0.0	1.1

These two analyses were from the same furnace, taken within a short interval of time, and it is apparent that (2), the one with the incomplete combustion has the largest air supply. This leads to an examination of the causes of incomplete combustion, and it should be said that it is owing to irregular conditions with sufficient air, or to the air supply actually being deficient. With the former, an accumulation of ash and clinker on the grate, or irregular coaling of the fire, will result in CO being formed, owing to the gases and air passing away in masses without coming intimately in contact. When uniform conditions of fire are maintained, the air supply can be regulated so that CO2 will rise to a point above which it will be impossible to exceed, and any further air reduction, or increase in the fuel rate, will be followed by a drop in CO2 and the production of CO. This is the condition where the production of CO is properly chargeable to small air supply. The greatest attainable CO2 would be defined as the point of maximum CO2, which may vary in practice from 11 or 12 per cent to that of the theoretical; about 13 per cent, however, is a common point in the less efficient styles of furnaces. The author has often determined the point of maximum CO2 in different cases, but the example chosen to illustrate this feature is from coal dust fire, where the feed of fuel and relative air supply was under absolute control. Fig. 1 shows the curve beginning at 8.6 with a uniform coal feed; the air was reduced until the CO2 reached 13.5, when, with more reduction, it



dropped to 13, after which the air supply remained constant, and the coal feed was increased with the drop as shown. Previous to, and at maximum CO_2, analysis showed complete combustion; later, with the drop in CO_2 with increased coal, analysis showed incomplete combustion. The attainment of maximum CO_2 must be secured by proper manipulation, but the difference between maximum and theoretical CO_2 is a characteristic of the furnace itself.

What may be termed mixture is defined as that condition which causes a more or less intimate contact between the combustible and oxygen. The attainment of good mixture below the point of maximum CO_2 is dependent on the care in operation; and it is by securing good mixture that smoke may be prevented; the limit of perfect mixture is the point of maximum CO_2, and the difference between maximum and theoretical CO_2 is the measure of the excess of air necessary to secure complete combustion; this amount varies in different cases, and with different furnaces of the same kind. For example, the coal dust apparatus mentioned must be considered as a poor example in view of the reports of 17 and 18 per cent CO, with other installations. Fig. 2 illustrates the feature of mixture from the standpoint of analysis. This example is based on actual performance with a furnace where the mixture was ideal; with the maximum and theoretical point of CO_2 the same, and where the necessary excess of air for complete combustion was zero. It should be said that, as a matter of course, there was no sign of smoke. The line designated as "Total" is the volume of the absorbable gases; its height is governed by the sum of the curves beneath it, measured from the zero line of the diagram. It will be observed that as CO_2 rises, oxygen drops until it has disappeared, when CO_2 reaches maximum, which is also theoretical, and consequently the entire absorbable volume is CO2. This performance was secured with a constant air and a continually increasing coal supply; and when the point was reached where all of the air was used, the combination then proceeded in a gradually

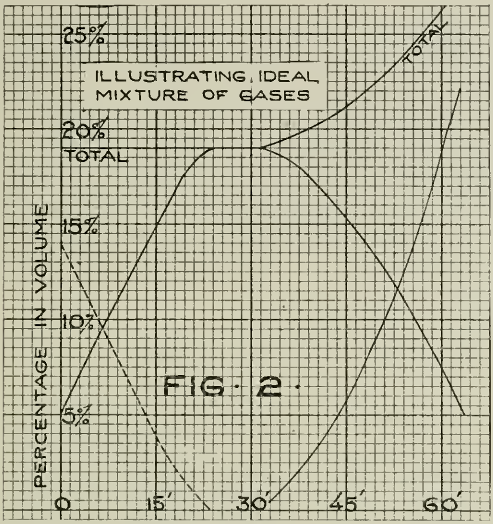


FIG · 2 ·

increasing CO and decreasing CO2, approaching a good producer gas mixture, with the result that the absorbable volume increased because the specific volume of CO is twice that of CO2.

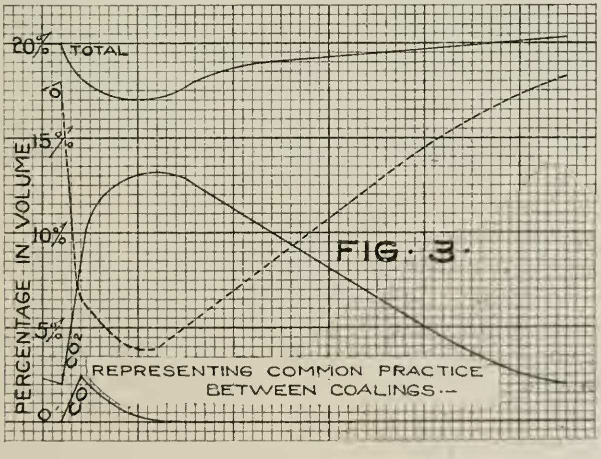


FIG · 3 ·

Fig. 3 represents performance covering a period from coaling an ordinary hand-fired furnace to the time that the fire was burned down. This represents the best generally prevailing practice. At the coaling, the CO_2 rises rapidly, while oxygen drops; but owing to the large amount of fuel supplied, the evolution of the volatile gases are in excess of the ability of the furnace to properly oxidize the combustible elements. The result is that CO is formed and some hydrocarbons are lost, accompanied by free carbon or smoke. It will be observed that when the process has attained complete combustion that CO_2 is at its maximum. The curve at the top of the diagram, representing the total absorbable volume, drops at coaling, because at this time the hydrogen that is burning is relatively greater than the carbon, and as the process continues the proportion of hydrogen becomes relatively less. Such performance has led some to assume that high CO_2 must necessarily be accompanied by the presence of CO, but under proper method of working this is not true.

Such practice as illustrated in Fig. 3 would be corrected as shown in Fig. 4, where the rises in CO_2 are small and at frequent intervals, owing to light and frequent coaling. The CO_2 by analysis is represented by the irregular changing curve, while that shown by the weighing instrument would be as an average, as exemplified by the smooth line. Under such conditions the air supply should be reduced or the coal rate increased until maximum CO_2 was attained, and if further continued would result in reduction of CO_2 and formation of CO, and under this condition air would still be present.

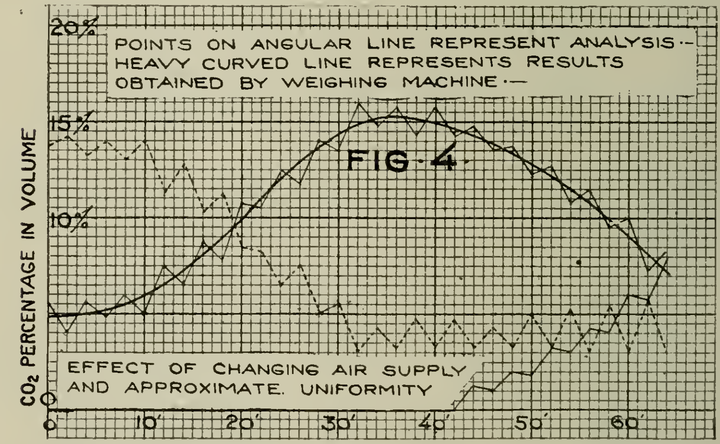

FIG·4·

Fig. 5 is interesting as showing the remarkable performance as ash and clinker accumulates on the grate, causing CO and excess of air to increase together.

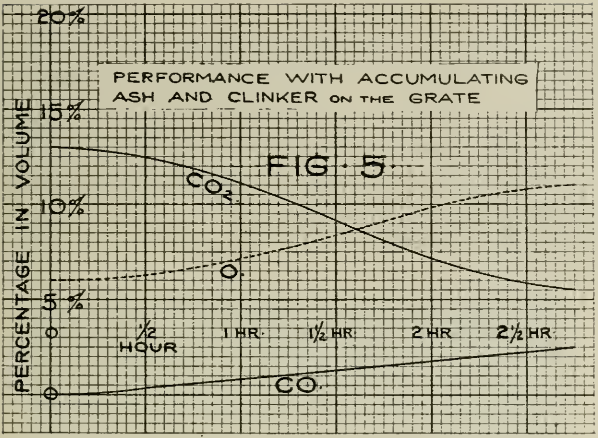

PERFORMANCE WITH ACCUMULATING ASH AND CLINKER ON THE GRATE

FIG. 5.

In view of the fact that the cause of incomplete combustion is so often attributed to insufficient air supply, the following condition will bear examination from this standpoint:

Carbon dioxide	8.2
Oxygen	8.9
Carbon monoxide	1.9

As it is, the air is in objectionable excess, and any further increase would make this feature worse, or a decrease would promote the incomplete combustion; therefore, there would be no remedy from changed air supply. It is, of course, true that incomplete combustion is always owing to insufficient air supply as far as the individual atom of carbon is concerned, but it is not true in its relation to the entire volume. The only remedy in such case would

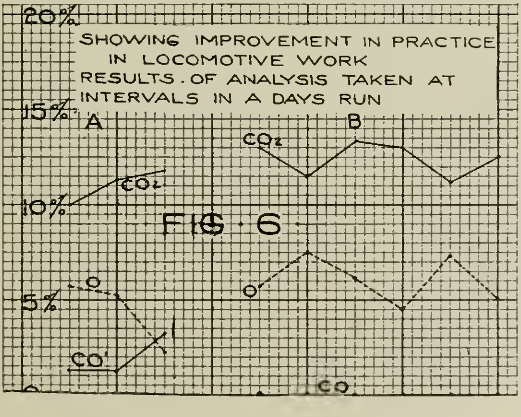
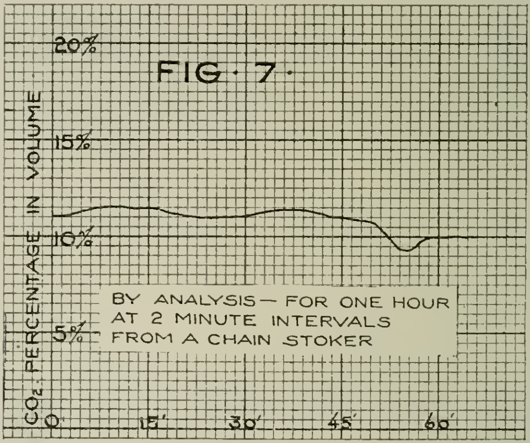

SHOWING IMPROVEMENT IN PRACTICE IN LOCOMOTIVE WORK RESULTS OF ANALYSIS TAKEN AT INTERVALS IN A DAYS RUN

FIG. 6.

be to correct the conditions, and to illustrate what may be done in this line, Fig. 6 is submitted. In this each set of points represents an analysis, and the group A shows the former practice and B the improvement. It will be interesting to know that the draft was less and the amount of coal was burned greater with B than with A.

In view of the foregoing, it is to be expected that confidence could be placed in the knowledge of the amount of CO2 considered in relation to prevailing conditions.

The following examples show the application of the proposed method:



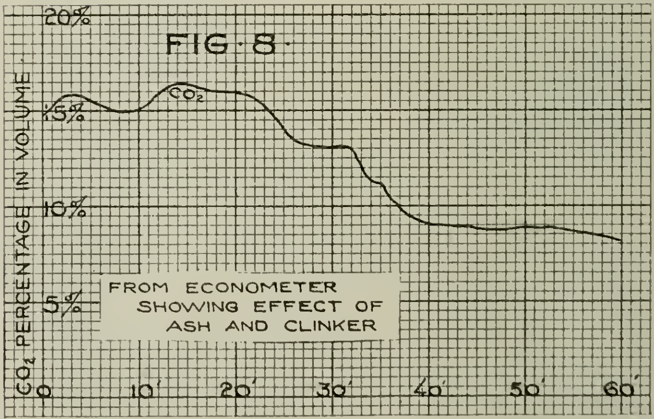


Fig. 7 is a very uniform performance from a chain grate stoker, from analysis at two minute intervals for one hour; the gradual and slight rises were caused by the effect of a slightly changing steam pressure on the stoker engine, which was not provided with a governor, and as its speed increased, slightly more coal was fed, with a rise in CO2. The drop at the end was caused by the fireman checking the speed of the engine. As the rises were caused by more coal, and the drops by less coal, it shows that combustion was complete and which was verified at the time by analysis.

Fig. 8 shows very well the effect of accumulating ash and clinker on the grate; the curve is from 60 observations during one hour.

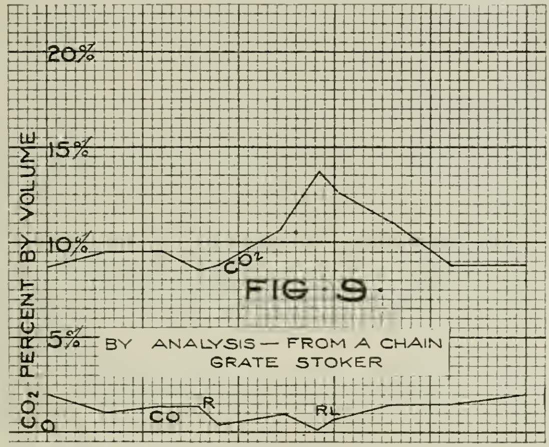


FIG · 9 ·

BY ANALYSIS — FROM A CHAIN GRATE STOKER

Fig. 9 is from a chain grate stoker with the unusual condition of small air supply. The curves illustrate the condition at a time, when, at the point marked R, the fire was raked and broken up with the effect shown; but at the point RL, when the fire was carefully

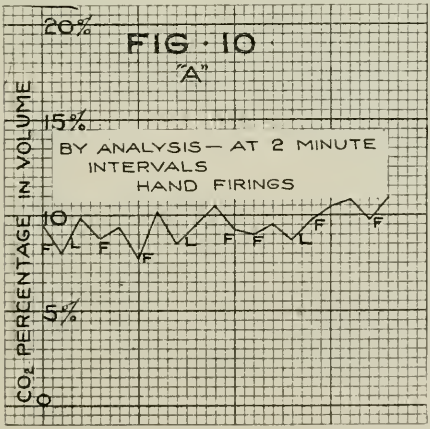
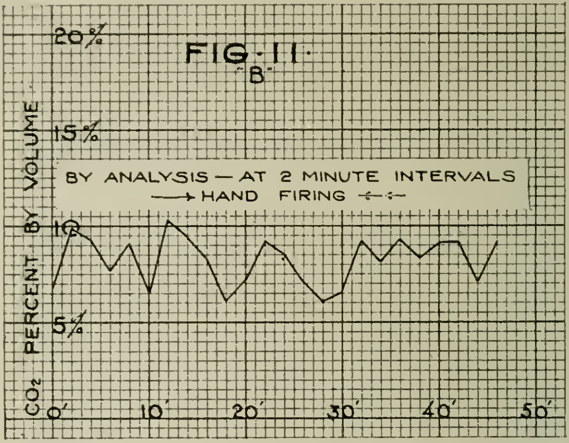


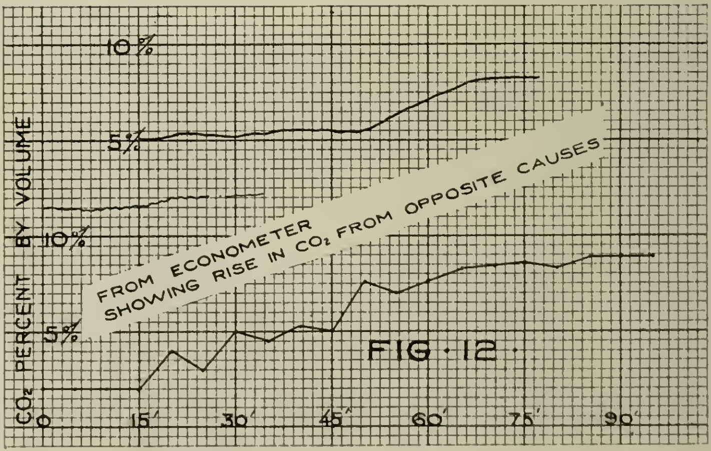
FIG · 10
"A"

BY ANALYSIS — AT 2 MINUTE INTERVALS
HAND FIRINGS

raked and leveled, the improvement is marked, after which the fire settled back into its old condition. This illustrates the value of skillful supplementary hand work with stokers.

Figs. 10 and 11 are from the same hand fired furnace, taken by analysis at two minute intervals within a period of two hours; but the firing was by different men. The coalings are designated as F, and it will be observed that, with one exception, the CO2 rises with the work of the man in Fig. 10, but with the other man's work in Fig. 11, every coaling but one shows a drop in CO2. At points designated L, the fire was leveled and the marked improve-


FIG·11·


FIG·12·

ment is apparent. The higher average and uniformity of one over the other is another feature that also serves to show the great difference between two men with the same furnace, coal and general conditions.

Fig. 12 from the econometer shows rises in CO_2 from opposite causes. Curve A began with an enormous excess of air, and the condition was such that it was impossible to keep up the steam pressure, although a very large amount of coal was burned. The trouble came about through a change from screenings to a small lump coal, and the method of working had not been altered to suit the change, with the result that an enormous amount of air flowed unused through the fuel bed. When the fire was carried very much thicker, the CO_2 went to 9, and the steam to the desired pressure. With B the condition was very bad from careless work on the part of the fireman, as shown with CO_2 at 5 per cent; the demand for steam dropping off, the man ceased firing, with the result that the CO_2 advanced as shown.

Fig. 13 shows the results from a gravity fed stoker — under these conditions—of the work as done by two different men, and under improved conditions.

The observations were from the econometer at two and a half minute intervals. The period between cleaning fires is about two hours.

The line "A" shows the results when the fireman labored under the impression that it was necessary to force the coal from the hopper by hand in addition to that supplied by the automatic feed. The points where the coal was so introduced is designated as P; with each there is a drop in CO_2, which was accompanied by incomplete combustion, loss of hydrocarbons and smoke. The time of cleaning fire is designated by FC in each of the diagrams. It was considered necessary to use a thin slice bar through the sloping grate, for the purpose of detaching accumulating clinker and assisting it and the coal on the descent. While the man whose work is shown in line "A" did not use this slice bar, the one whose work is shown in the line "B" used it in the extreme manner indicated by the drops designated as S; but as he did not force coal in by hand, all of the drops are from excess of air. The full line "C" shows the corrected practice where the automatic feed supplied all of the coal, and slicing through the grate was done in an intelligent and careful manner, with the result that there was no smoke or incomplete combustion. At the point designated FR, the feed of coal was reduced preparatory to cleaning the fire.

From the foregoing illustrations it will be observed that CO_2 will drop with increased excess of air or with incomplete combustion. It is not necessary to know the exact percentage of

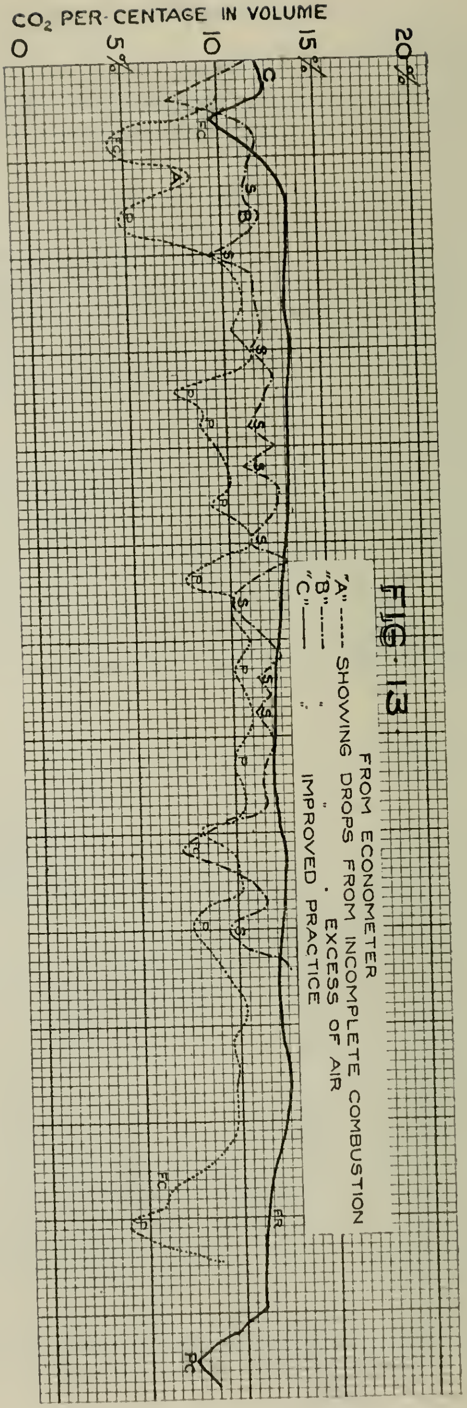

CO₂ PER-CENTAGE IN VOLUME
0
5%
10
15%
20%
C
A
B
S
P
FC
PC
ER
FROM ECONOMETER
"A" ------ SHOWING DROPS FROM INCOMPLETE COMBUSTION
"B" -.-.-.- " " " EXCESS OF AIR
"C" ——— " IMPROVED PRACTICE

FIG. 13.

excess of air or the amount of the incomplete combustion loss. It is sufficient in regular working to know that the condition is bad, and to have the cause indicated. The remedy may then be applied.

DISCUSSION.

Prof. Breckenridge—I wish to say that I have read this paper with considerable interest. It illustrates graphically and in a very clear manner some things about the operation of furnaces which we are liable not to get into our heads unless we see the pictures. I had sort of an idea that carbon dioxide and oxygen would go up and down separately, while, as a matter of fact, if the carbon dioxide increases, the supply of oxygen must increase, and Fig. 3 in the chart, I think, brings out this relation as clearly as anything I have ever seen. I think the thanks of the Society are due Mr. Bement for presenting these facts in this way before us. I was sorry that he did not think it well to speak of the apparatus which he used to make these determinations, but I suppose his modesty held him back. The econometer which we have at the University of Illinois we have found useful and very instructive. I think it requires to be used by some one who takes an interest in it, and arranged so that the fireman himself understands what it means when the percentage of carbon dioxide goes up, and that he should be instructed to keep the pointer pointing as high as at least 12 or 14 per cent, and know that when this is the case, his furnace is operating under the most advantageous conditions.

I wish to compliment Mr. Bement for the nice manner in which the whole subject has been presented in this paper.

Mr. Abbott—I regret that I have not had an opportunity to study this paper as thoroughly as I should. I had expected it would be read this evening. However, I have looked it over to some extent.

I will say, generally, that there is, as most every one of us knows, a wide difference between what can be obtained in general practice and what can be obtained on tests. You might make a series of tests on a certain fuel and the results would point, say, toward the Promised Land, and on trying them later on, under ordinary conditions, unless you have the most careful management of your boiler-house, you will find your results will then point in the opposite direction. I am becoming impressed more and more with the fact that the boiler room usually does not receive the attention to which it is entitled, and that, instead of spending so much attention and providing the very best superintendent for the engine room, if these were divided between the engine room and the boiler room, the results which would be obtained in the latter place would far outweigh any possible improvement which might be made in the engine room.

In ordinary boiler practice the efficiency of the boilers is probably not greater than 50 per cent and as low as 40 per cent. Good practice, however, can bring this up to 70 per cent, and in some cases as high as 80 per cent. Now, there is that chance of a possible improvement of 30 per cent, or in some cases 50 per cent which may be made by proper attention to the work of the boiler room.

I think that Mr. Bement's work along this line, and the attention which he is bringing to the subject of fuel combustion, is one of very great importance, and he should receive our encouragement in his work in this direction.

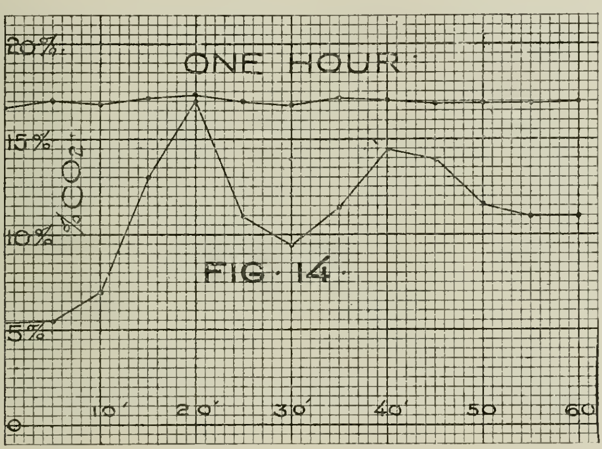
Mr. Gasche—I must confess lack of close familiarity with the paper. Owing to certain pressing matters I have not been able to study the contents of the same, and consequently feel some hesitation in discussing this particular problem, viz., the continuous examination of flue gases from boilers. The process might quite as well apply to heating furnaces. The device in question will unquestionably serve a very valuable purpose to the engineer in the operation of his furnaces for the obtainment of the results desired, but it seems to me that it is to be looked upon chiefly as an instrument for the examination of possible defects existing in our boiler furnaces.

As to its continued application or employment, I am inclined to think it might be a very valuable device in a boiler room. But the problem that will almost immediately appeal to the engineer who has to deal with power in large units will be the application of this device to large batteries of boilers, in which case, it seems to me, there will be great difficulty in utilizing instruments of this character.

Prof. Kerr, of Armour Institute—I am like some of the other gentlemen and have not read Mr. Bement's paper very thoroughly. One point I would like to ask Mr. Bement to explain to me; that is, why, when we get this condition we call maximum CO_2 we cannot maintain it. It seems to me it would be very desirable if we could do so. The paper as a whole shows some very interesting results to those who are interested in these matters at all, and among the most interesting things to me are those near the close, showing the defects of different methods of handling fire, even by firemen who are experienced. I think Mr. Bement is to be complimented on the way he has carried out this thing, and the clear way in which it is presented.

Mr. Bement—As Mr. Gasche has intimated, there is great difficulty in introducing gas analyzing instruments and methods, and the work may only be profitably undertaken in cases where the technical personnel of the operating force is considerably above the average. Mr. Abbott has called attention to the necessity of better superintendence for the boiler plant, and it is usually necessary to place a man of higher intelligence directly in charge of boiler operation before satisfactory results may be had, and where this plan has been adopted the results in most cases are very satisfactory, and some important improvements have been made in a number of cases.

In reference to Prof. Kerr's inquiry as to why the CO2 changes, or the condition of combustion, which is the same thing, it should be said that it is caused by an irregular condition of the fire. If the process is to be uniform, it implies a uniform condition generally, such as feed of coal, condition of fire and air supply. With hand firing it becomes an artistic performance. In this connection the diagram herewith submitted (Fig. 14) is of interest. It represents performance on two different occasions with the same chain grate stoker. In each case the feed of coal, draft and working conditions were the same, and while in one case the excellent and uniform condition of 17 per cent of CO2 was attained, in the other, the combustion process went through the remarkable changing conditions shown by the very irregular curve, caused variously by excess of air or incomplete combustion; also a good condition for a brief interval. The trouble came from the method used to work the particular fuel then employed, and the condition of combustion was influenced by the fire itself.



Results on two different occasions with the chain grate stoker and same fuel, but the condition of combustion in one case was modified by the fire itself.

CXXI.

BOILER TESTS WITH ILLINOIS COALS.

By L. P. Breckenridge,
Professor of Mechanical Engineering, University of Illinois.

Read May 1, 1901.

During the last seven years the Department of Mechanical Engineering at the University of Illinois has conducted nearly one hundred and fifty (150) boiler tests.

These tests have been made principally at the power plants of the University. Three years ago, however, the old plant of the University was abandoned and a new one built, so that the tests have been made under considerably different conditions.

Tests have also been made at several of the power plants of the cities of Champaign and Urbana. It has seemed to the writer that a report of the results of these tests might prove of some interest and be worth recording in the Journal of this Society.

Of no less value and interest is an analysis of the coals tested (Plates 5 and 6), as well as various boiler water analyses, and a table of these analyses is also given (Plates 7 and 8). These analyses have been largely made by the Department of Applied Chemistry under the direction of Professor S. W. Parr.

The Coals Tested. While a large number of the tests have been made with the coals purchased under the yearly contracts of the University, still a considerable number of tests have been made on special coals purchased for that purpose, or on coals sent to the University by various coal companies, or by different manufacturing concerns wishing evaporative tests of certain coals made.

The commercial names of the coals tested are given in the following list:

1. Athens lump
2. Bloomington lump
3. Du Quoin lump
4. “ slack
5. Fairmount screenings
6. Moweaqua lump
7. Muncie slack
8. Mt. Olive lump
9. Niantic nut
10. Odin pea
11. “ lump
12. Pana screenings
13. Pana slack
14. “ lump
15. Paradise lump
16. Sangamon “
17. Junction pea
18. Ridgely “
19. Dawson “
20. Riverton “
21. Sangamon “
22. Danville screenings
23. Muddy Valley lump

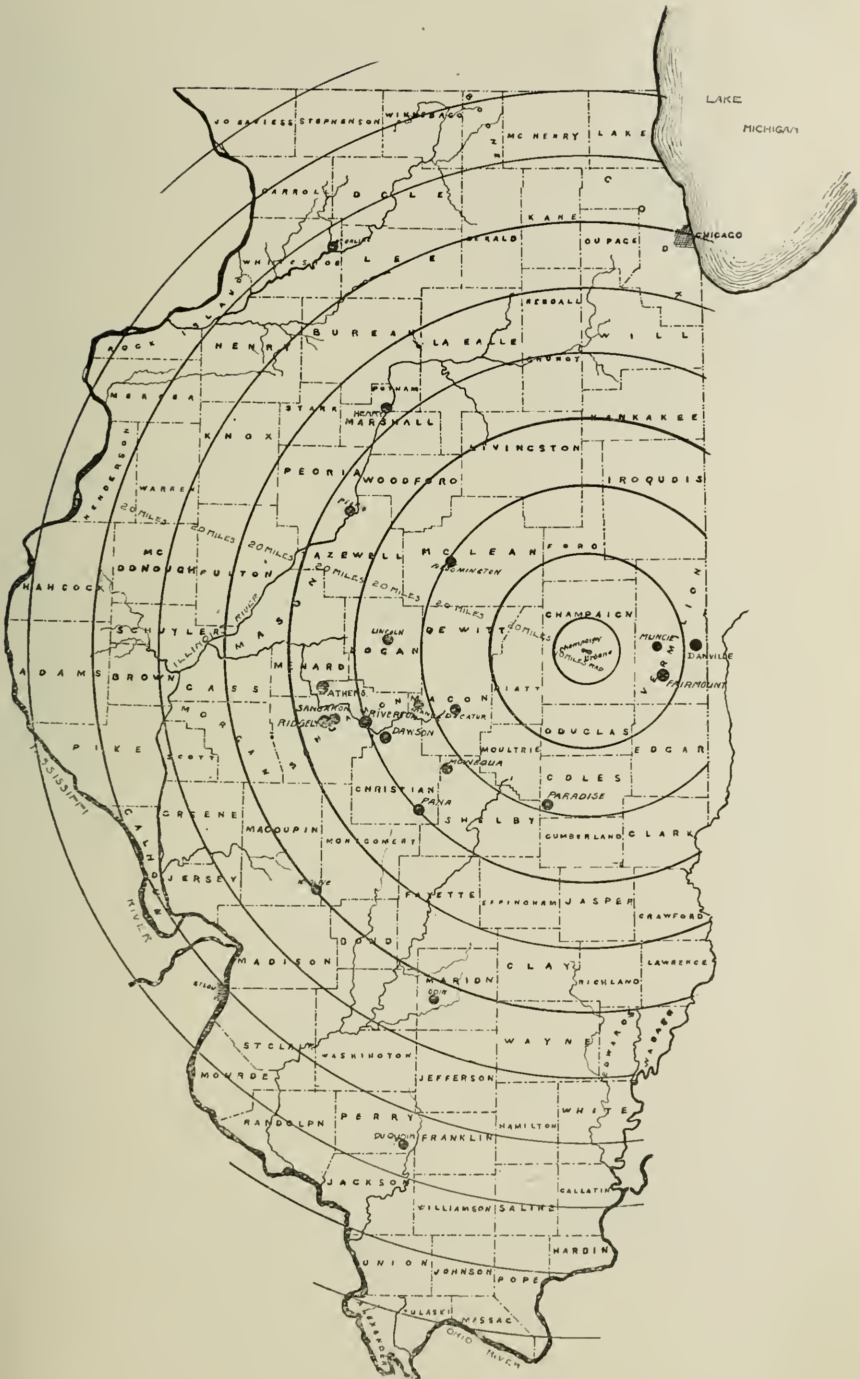

LAKE
MICHIGAN
CHICAGO
JO DAVIESS
STEPHENSON
WINNEBAGO
MC HENRY
LAKE
CARROLL
OGLE
KANE
DU PAGE
COOK
WHITESIDE
LEE
DE KALB
KENDALL
WILL
ROCK ISLAND
HENRY
BUREAU
LA SALLE
GRUNDY
MERCER
PUTNAM
STARK
HENRY
MARSHALL
KANKAKEE
KNOX
LIVINGSTON
HENDERSON
WARREN
PEORIA
WOODFORD
IROQUOIS
20 MILES
20 MILES
20 MILES
MC DONOUGH
FULTON
TAZEWELL
MC LEAN
BLOOMINGTON
FORD
20 MILES
20 MILES
20 MILES
20 MILES
HANCOCK
SCHUYLER
ILLINOIS RIVER
MASON
LINCOLN
DE WITT
CHAMPAIGN
Champaign
Urbana
20 MILES RAD
MUNCIE
DANVILLE
VERMILION
FAIRMOUNT
ADAMS
BROWN
CASS
MENARD
LOGAN
PIATT
ATHENS
SANGAMON
RIVERTON
MACON
DECATUR
RIDGELY
DAWSON
DOUGLAS
EDGAR
MORGAN
SCOTT
PIKE
MOULTRIE
MONEQUA
COLES
CHRISTIAN
PARADISE
PANA
SHELBY
MISSISSIPPI
CALHOUN
GREENE
MACOUPIN
MONTGOMERY
CUMBERLAND
CLARK
JERSEY
FAYETTE
EFFINGHAM
JASPER
CRAWFORD
RIVER
BOND
MADISON
CLAY
LAWRENCE
RICHLAND
MARION
ODIN
ST LOUIS
ST CLAIR
WASHINGTON
WAYNE
EDWARDS
WABASH
MONROE
JEFFERSON
WHITE
RANDOLPH
PERRY
HAMILTON
DU QUOIN
FRANKLIN
JACKSON
GALLATIN
WILLIAMSON
SALINE
HARDIN
UNION
JOHNSON
POPE
PULASKI
MASSAC
ALEXANDER
OHIO RIVER

FIG. 1.

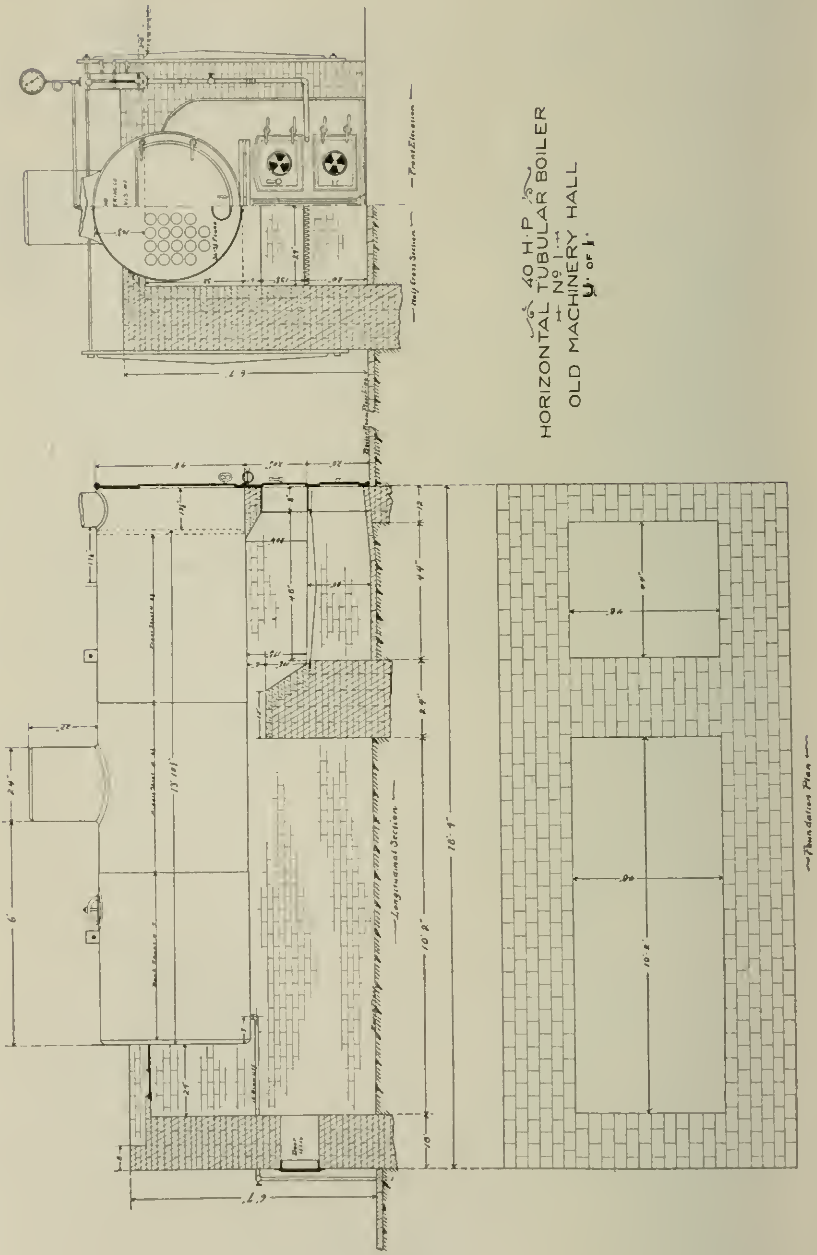

40 H.P.
HORIZONTAL TUBULAR BOILER
No 1
OLD MACHINERY HALL
U. of I.
Front Elevation
Half Cross Section
Longitudinal Section
Foundation Plan
18' 4"
10' 2"
13' 10½"
6'
24"
44"
24"
12
10
24
Door

FIG. 2

The location of the mines from which these coals came is for the most part indicated by the name of the coal, which usually takes the name of the county or town in which the mine is located. On

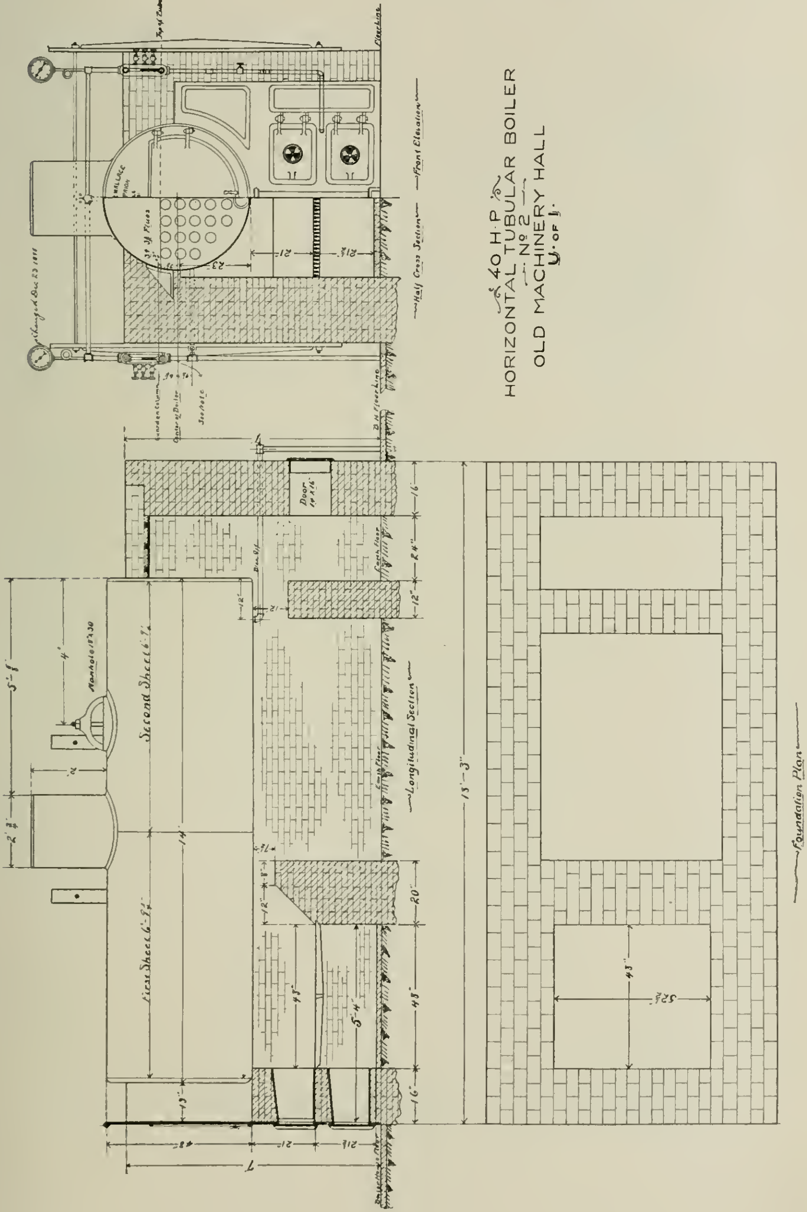


FIG. 3.

Fig. 1 is also shown the location of the various mines from which the coals have been obtained. The circles drawn with Urbana as a center are each 20 miles apart.

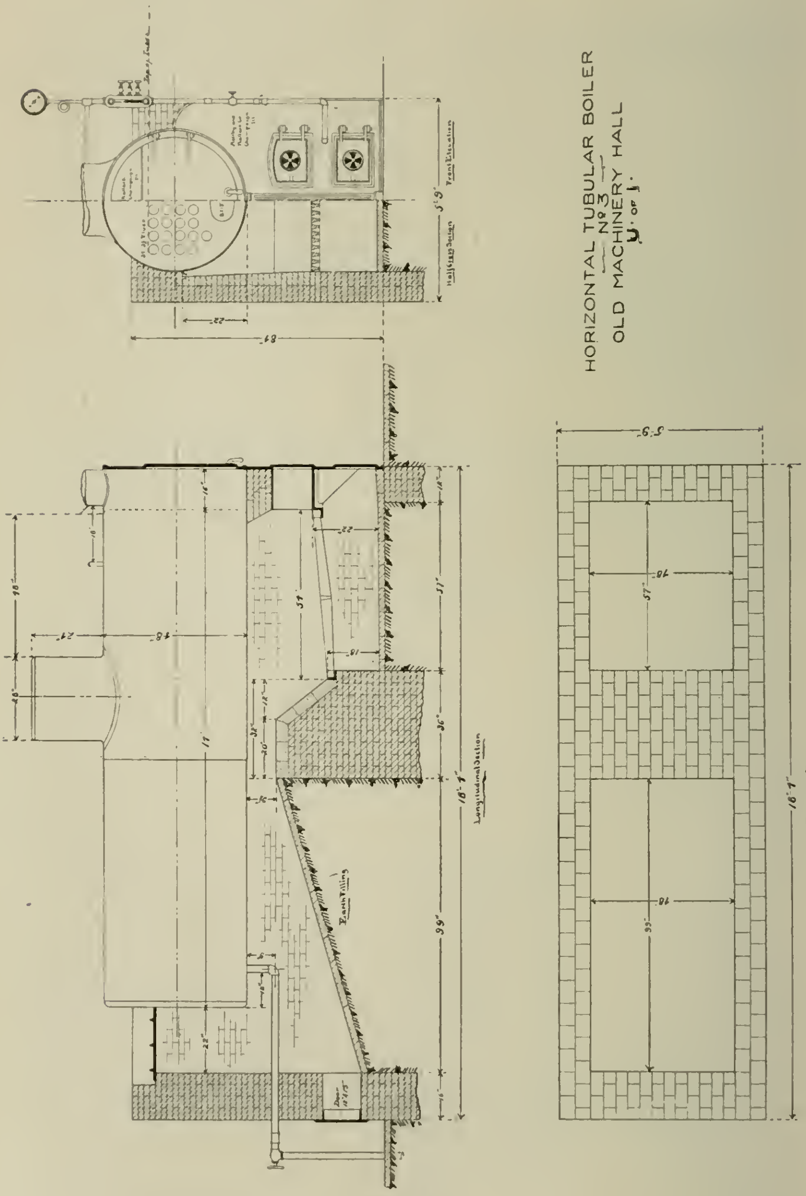


FIG. 4.

The Boilers.—The tests have been made under boilers of the water tube type and of the fire tube type, as follows:

1. Stirling water tube boiler, 1 setting.
2. National " " " 1 "
3. Babcock & Wilcox water tube boiler, 8 settings.
4. Horizontal tubular boilers, 10 "

These boilers are located in eight (8) different plants in the vicinity of or at the University of Illinois. One "Murphy Smoke-

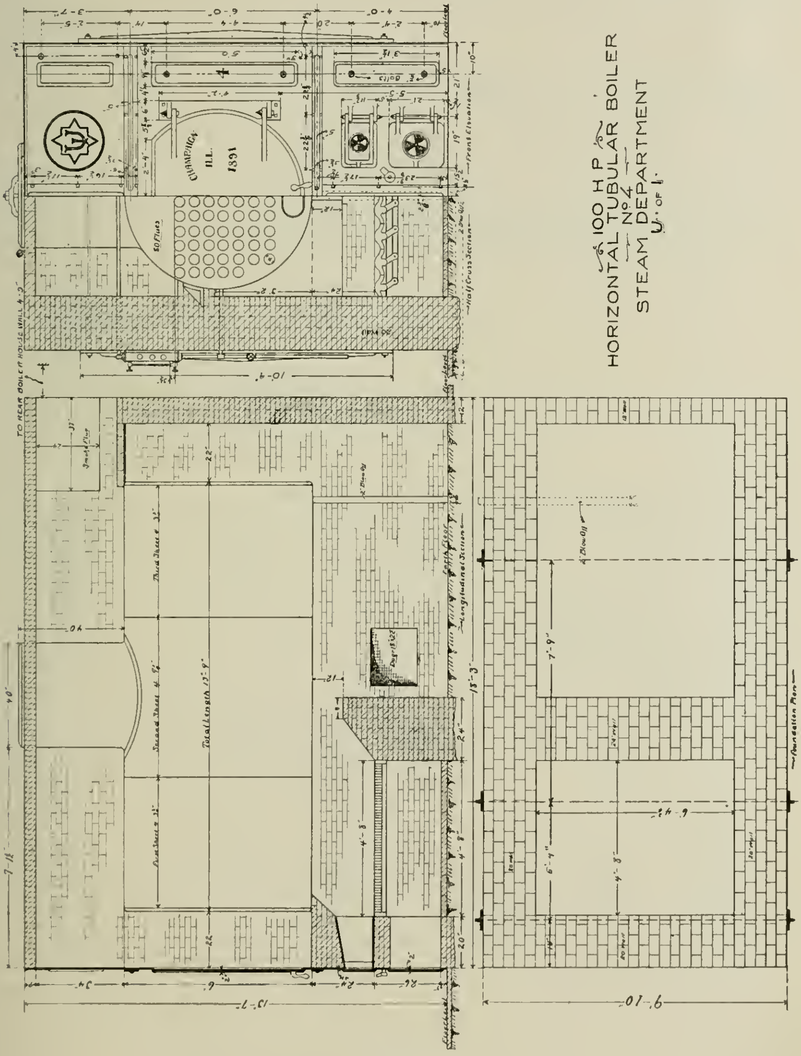


FIG. 5.

less Furnace," one "Brightman Stoker," two "Roney Automatic Stokers," and one "Babcock and Wilcox Chain Grate," are included among the settings, the remainder of the furnaces being hand fired.

Figs. 2 to 9 exhibit the characteristic features of the boilers, settings and furnaces.

The internal condition of the boilers at the University plants was good, being almost as clean as new boilers, due to the fact that the condensed water from the heating system was used.

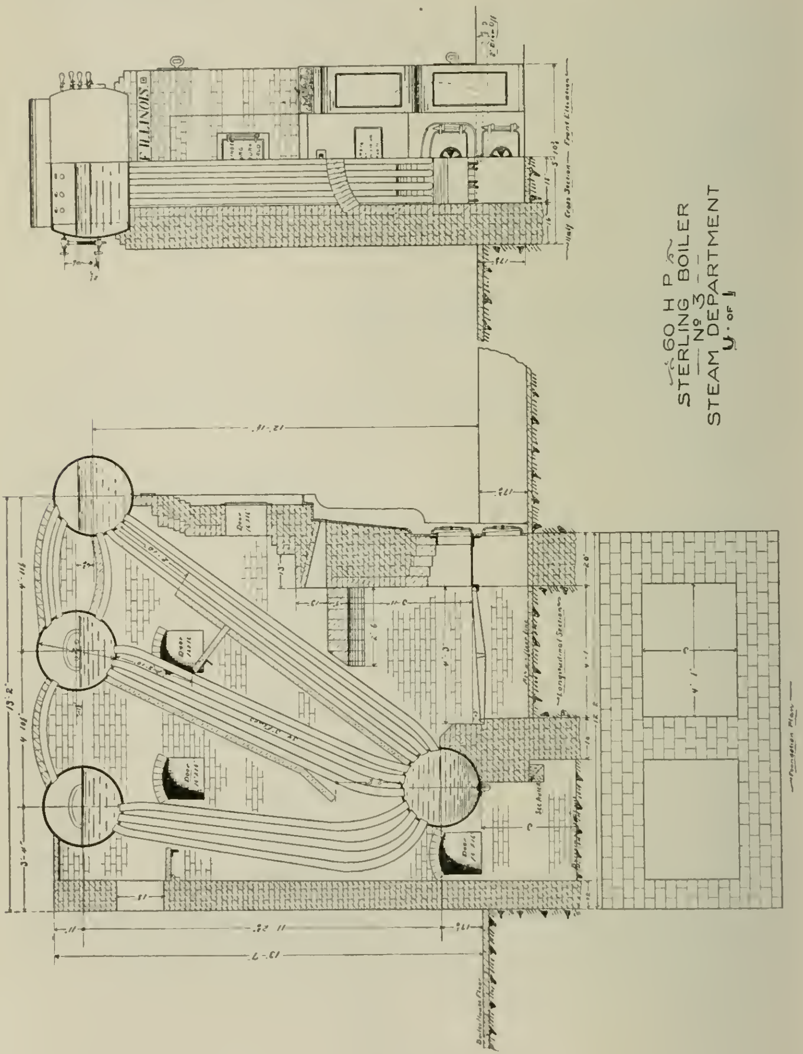


Fig. 6.

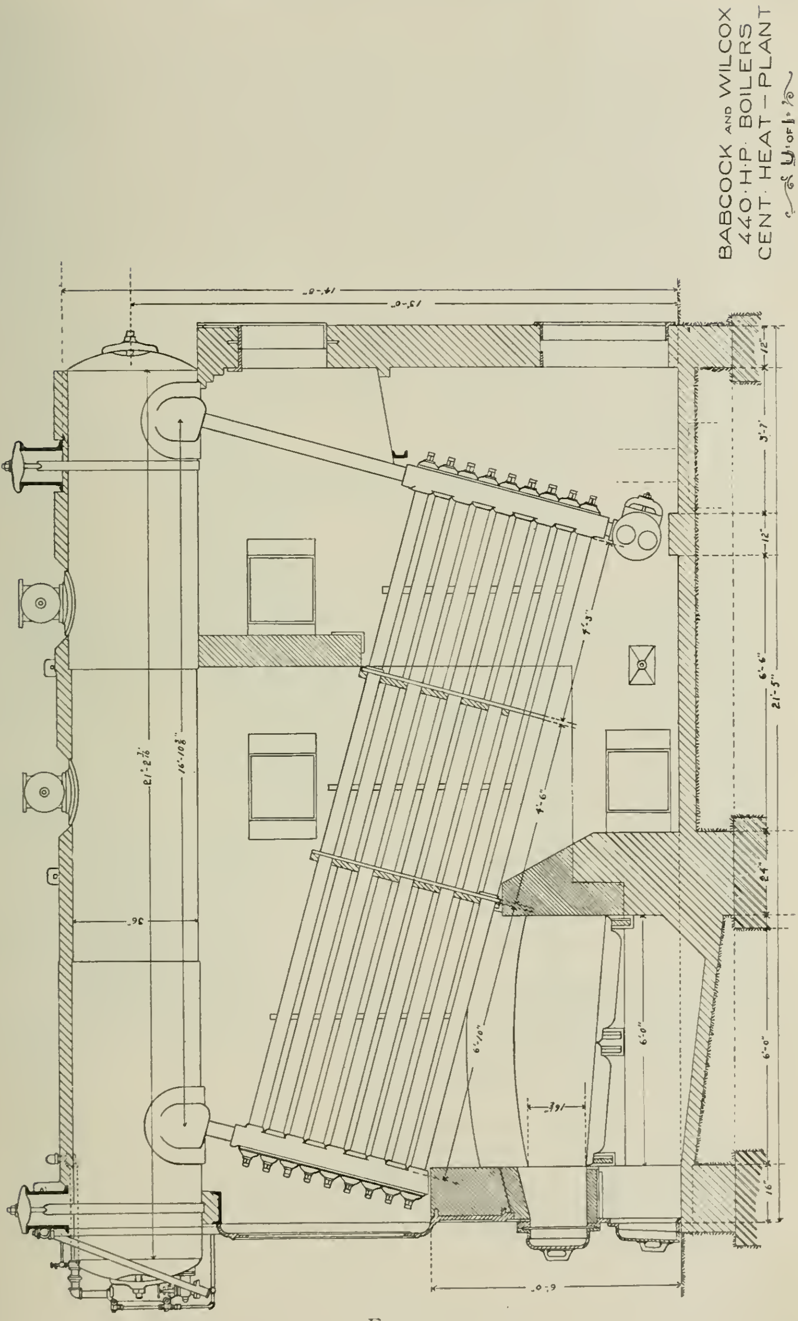

BABCOCK AND WILCOX
440 H.P. BOILERS
CENT. HEAT – PLANT
U of I.
14'-8"
15'-0"
12"
3'-7"
12"
6'-6"
21'-5"
24"
6'-0"
16"
21'-2½"
16'-10⅝"
36"
4'-3"
4'-6"
6'-10"
16"
6'-0"
6'-0"

FIG. 7.

The Tests.—The results of these tests are exhibited in Plates 1 to 4, and the headings of the tables need no explanations. The tests numbered 1 to 55 were all made on various settings of horizontal tubular boilers, while tests numbered 101 to 151 were made on boilers of the water tube type. The proportions of most importance and interest are also included in these tables.

It should be borne in mind that most of these tests were made under every-day running conditions that happened to exist in each case. It is on this account that the tests may have a greater value

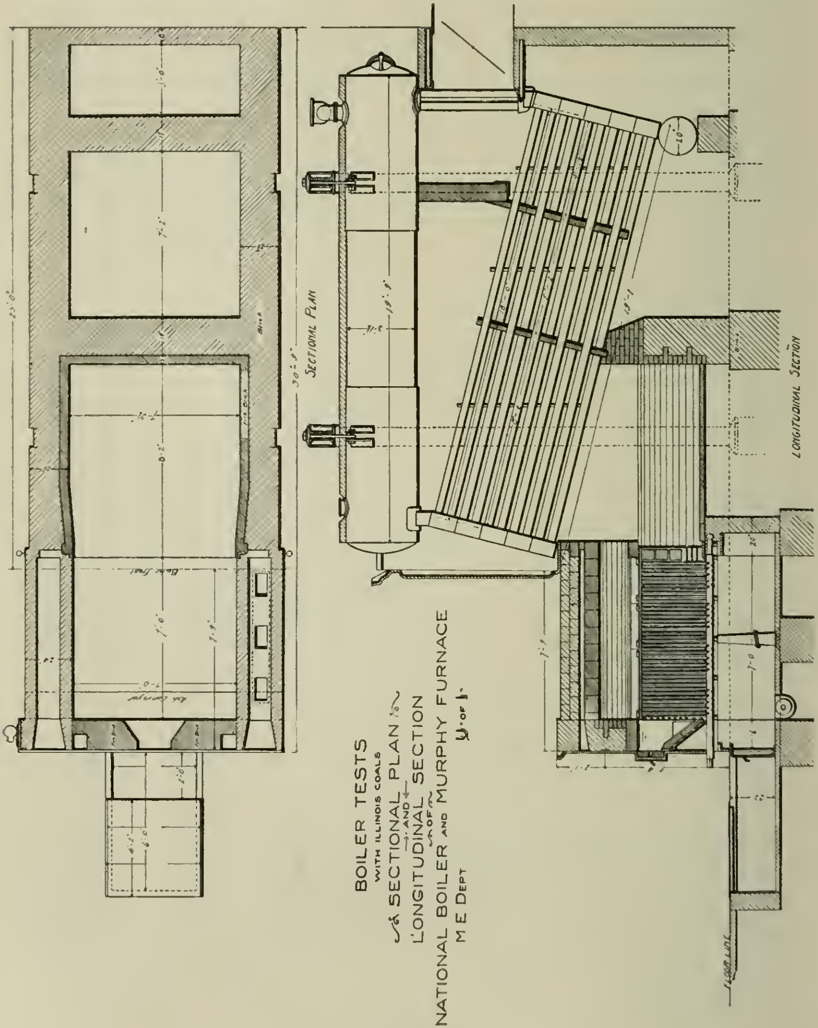


FIG. 8.

than tests made to demonstrate the peculiar merits of this or that type of boiler, furnace or setting. Considerable care was taken in all cases to insure the accuracy of all instruments used in the tests, and in most cases the frequency of the observations was greater than is sometimes possible with a limited number of observers.

It was the intention of the writer to make some systematic grouping of the result of these tests, but it has not been possible to do so for lack of time. It is the intention to continue these tests from year to year, and with the present improved facilities and with the growing co-operation of coal operators it is hoped much more extensive and careful work may be done.

Remarks.—Much discussion of the problem of the economical burning of Illinois coals cannot be entered into in connection with this article. The writer wishes, however, to make a few remarks

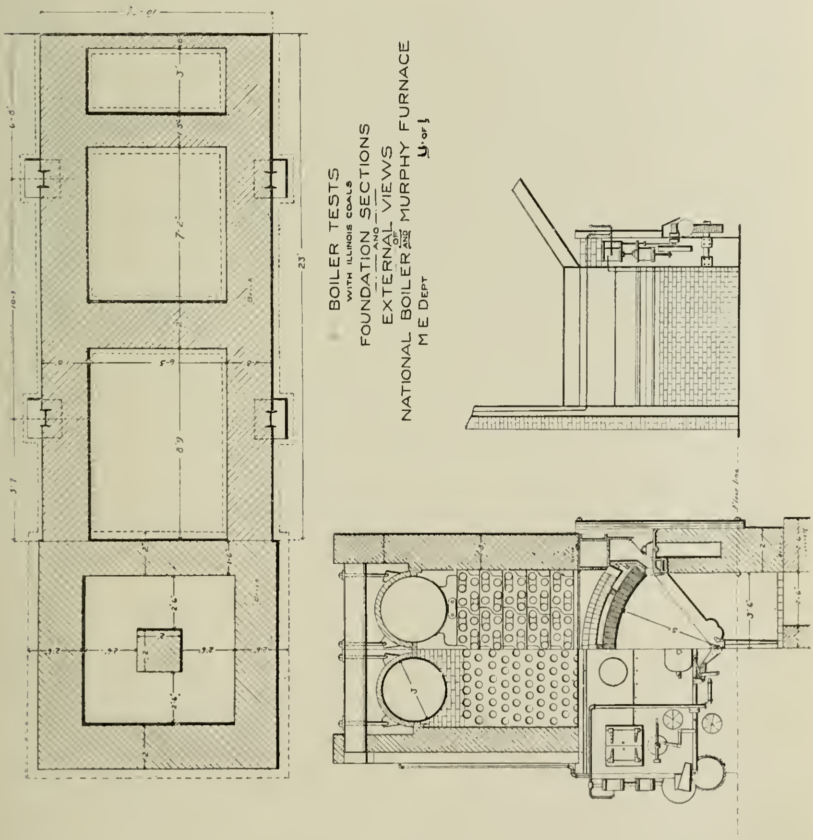


FIG. 9.

on this subject as the result of his experience in this field of experimentation. The large percentage of volatile matter contained in nearly all the Illinois coals makes it much more difficult to secure complete combustion, and renders very slight changes in furnace construction or operation responsible for widely varying results.

Insufficient draft is responsible for a very considerable loss of effect in the burning of Illinois coal. While a draft of from three to five-tenths inch of water gives excellent results with coals having 60 per cent of fixed carbon, it is found that for most Illinois coals it is better to provide from six-tenths to one inch if the highest results are to be obtained. Poor draft is also responsible for much smoke. The distance from the grate to the heating surface is frequently too small. Instead of the 24 to 30 inches commonly found under horizontal tubular boilers, it is probable that 30 to 36 inches would give better results.

Illinois coals may be burned with but little smoke. To accomplish this most successfully some form of automatic stoker or special furnace will be required. It will also require an intelligent fireman.

The failure of architects and owners to provide suitable space for the installation of modern furnaces, and decent quarters for intelligent firemen, is good and sufficient reason for the production of the greater part of the smoke which is so easily made from most grades of Illinois coal. One of the most efficient means of obtaining economy, and at the same time preventing smoke, is the proper introduction of a fire brick arch, arranged so as to prevent the products of combustion coming into contact with the shell or tubes of the boiler until the union of the carbon and oxygen has taken place.

The introduction of coal washing machinery is proving very beneficial. Washed nut coal may be burned in most house heating boilers without producing smoke. It does not clinker and it is almost as clean as hard coal. Frequently too large a grate surface is provided for a boiler for the work required, and the economy may be increased and the smoke lessened by reducing this area.

DISCUSSION.

President—We cannot hope to do justice to this paper in the time at our command, but we can make a beginning.

Mr. Guthrie—I would like to ask Prof. Breckenridge if in these tests he has made any effort at varying the supply of air between the times of firing, or whether a uniform supply of air was given all the time, from the shoveling in of the coal until the next supply was put in; and whether the driving off of the gas required a larger supply of air?

Prof. Breckenridge—No, we have not done that. We have made these tests just as we have found the boilers, the tests consisting mostly of trying to find how much water would be evaporated by a pound of coal.

Mr. Bement—In reference to the diagram showing various boiler efficiency at different capacity, based on pounds of water evaporated per square foot of heating surface, on examining the curve of maximum results it appears that the best performance is with an evaporation of 2 to 3.5 pounds per square foot, and with further increase in capacity the efficiency drops very rapidly. It is probable that this illustration may convey the impression that the efficiency of the boiler will fall off at the rate shown, with the capacities as indicated by the evaporation per square foot. Now I have had the efficiency increase up to the evaporation of 10 and 11 pounds of water per square foot of heating surface, and this is a performance just opposite to that indicated by the curve of maximum results. The matter certainly requires an explanation. I think we fail to realize the great importance the furnace has on the boiler, or, in other words, the condition of combustion; also that the performance of the steam generating apparatus—by this I mean the combination of furnace and boiler—may suffer more than we realize owing to unskillful operation. I believe that the efficiency of the boiler is greater than is generally supposed. Strictly speaking, to my knowledge there has never been such a thing as a *boiler* test. By this I mean an experiment to determine accurately its heat-absorbing or gas-cooling capacity. For illustration: if two boilers were served with the same number of pounds of gas of the same composition and the same initial temperature—this latter would be implied, however—the boiler abstracting the most heat would be the most efficient. If we are to do the boiler justice we must serve it with the combustion gas best suited to its requirements, which would be the product of complete combustion with minimum air supply, which would be also the condition of maximum CO_2. This is necessary, because if combustion is incomplete the heat is not present to be taken up, and if the air is in excess, the heat-absorbing capacity will be reduced in proportion to the volume of the gases; likewise the loss will be in proportion to the volume of the escaping gases. I think if we are to deal with boiler efficiency, it should be on the basis of a standard combustion gas composition, because the efficiency of the boiler may be as low as 20 per cent with complete combustion, owing to excessive amount of air being present.

As a rule, the information concerning trials of steam generating apparatus is not complete; the composition of the gases is not often determined in this country, although some of the leading experts now make good use of gas analysis, and as far as I know there is no published report of a trial, wherein evidence is submitted that effort was made to attain maximum efficiency; yet no trial can be of value unless this feature is determined. In a speed trial of a steamship they are not satisfied to measure whatever speed may happen to be attained, but on the contrary do everything to make the ship go as fast as possible. And so with a steam generating apparatus; both the maker and the purchaser should be interested in its true efficiency, and not be satisfied with the uncertain performance which might result from unskillful operation. There is a disposition in some quarters to decry what are called "fancy tests" and "expert firing," etc., and to state that such results were obtained with "ordinary firing" and with "common every-day practice;" but common every-day practice and ordinary firing may be such that a boiler will not make steam at all.

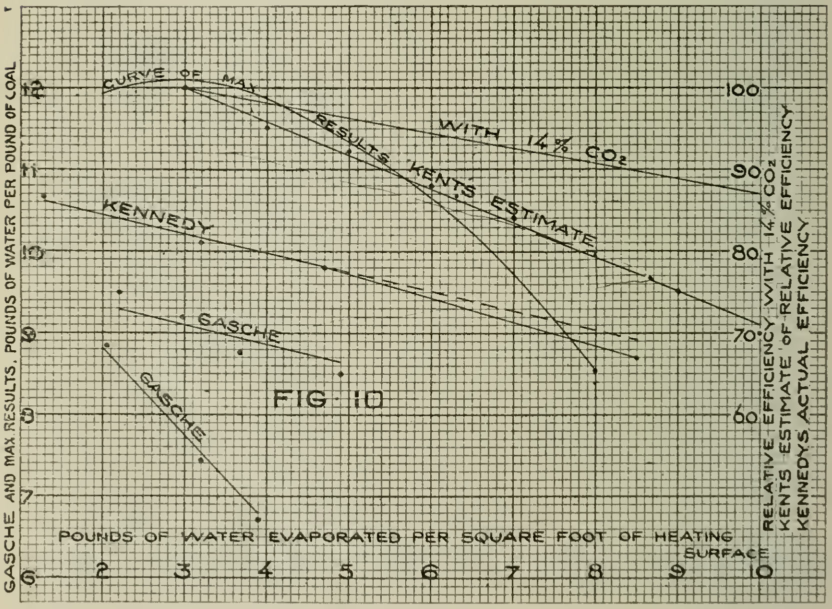


FIG 10

A diagram is submitted for the purpose of illustrating this matter of boiler efficiency. The only relation the curves bear to each other is their relative degree of inclination, showing the rate at which the boiler efficiency is assumed to drop with increase of capacity. Some are based on evaporation; others on efficiency. Those given as relative efficiency are based on the best attainable being 100; those designated as maximum results and "Kennedy," are from "Steam Boiler Economy," by Wm. Kent; those designated "Gasche" are from the JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS, Vol. 2, page 425; one with Murphysboro and the other with Mission Fields coals, and plotted in connection with pounds of coal burned per square foot of grate, but are here given in connection with water evaporated.

Kent's estimate is based on an assumed probable range of final temperature of gases of from 450 to 930 F., and would correspond to a condition of complete combustion with about 6 per cent CO_2. The curve designated "with 14 per cent CO_2" is based on the same range of tempeature, 450 to 930, but with 14 per cent. CO_2.

The four trials by Prof. Kennedy* were made with a Thornycraft boiler. The data bearing on the question in hand is as follows:

Number	1	3	4
Final temperature of gases	421°	610°	777°
CO_2	11.74%	11.68%	12 60%
O	7.71%	7.41%	4.45%
CO	0 10%	0.62%	2 30%

It will be observed that the efficiency drops off at a greater rate in the fourth trial, owing to incomplete combustion, but if the line through the first three trials be extended as indicated, it would, in a measure, show the correct relation as far as the boiler is concerned. It will be observed that there is a consistent agreement between the drops in efficiency shown by the 14 per cent of CO_2 Kennedy, and one of the Gasche curves as plotted. I would expect that the rapid drop in the other Gasche curve was from incomplete combustion. In regard to the curve of maximum results, it must be said that its indication is quite inconsistent in comparison with some of the others, and the only explanation I would offer is that its form was influenced by the furnace and not by the boiler.

I am much impressed by the good performance possible with boilers worked at large capacity, by finding that, as a general rule, as soon as I work the apparatus for higher efficiency, I get more horse power than I can use, which means that either a less number of units must be kept in service, or that grate surface or draft must be reduced. This refers especially to the burning of bituminous coal.

Mr. Sorge—My experience is entirely contrary to that of Mr. Bement. I have never yet found cases where, if the rate of combustion was largely increased, the efficiency of the boiler was increased. On the contrary, in all cases that I have had under observation, the lowering of the rate of combustion has increased the efficiency of the boiler; that is, has increased the number of heat units. So much so is this the case that, for instance, in one particular line which I am somewhat interested in, where the question of the increase in temperature of the feed water will ordinarily theoretically figure out an increased efficiency of approximately 1 per cent for every 10° raise of feed water, the actual experience that we have, through experiment and other trials, is that its increased efficiency runs from 1.2 to 1.4 per cent, although theoretically the 10 extra heat units which you might add are only about 1 per cent. In other words, by slowing up the heat transmission necessary for evaporation and decreasing the rate of combustion, we are able to increase the efficiency. I would very much like to have Mr. Bement's reference to some of the tests and records, where we could find where this increased rate of evaporation per square foot of heat surface would give us this increased efficiency. I think that would be a very interesting thing to look into and to find out what the conditions were under which the tests where made. Prof. Breckenridge has given us a very interesting paper, and I only hope, when it is published, he will give us all the tables so we may see them.

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* Kent, Boiler Economy, page 299.

Mr. Bement—In reply to Mr. Sorge, I will say that the generally prevailing condition is that of too much air in the fire, whether combustion is complete or not, and an increase in the coal to satisfy the air will result in both increased capacity and efficiency up to the point of maximum CO_2, and the manipulation necessary to secure this result will also insure complete combustion. If, however, the coal is supplied in excess of the air, there will be incomplete combustion and efficiency will drop rapidly. But if combustion is maintained at the point of maximum CO_2 but the coal rate increased, the efficiency will fall, as shown by the curve of 14 per cent CO_2 in the diagram presented. This must necessarily be so, else a small boiler would be of the same capacity as a large one.

I have in mind a case where about 40 per cent of the units was shut down, with the result of increased efficiency with the same load. Mr. Merrill can tell us about it.

Mr. Guthrie—I am in hopes, within the next two or three weeks, to introduce air to the burning fuel without the aid of a steam jet, and in such a manner as to produce perfected combustion right at the surface of the burning coal. I hope to burn Illinois coal, or any other bituminous coal, without making any smoke and without the aid of steam, or if I do use any steam, it will be so small an amount as to be hardly worth considering.

Mr. Gasche—It is quite desirable that these limitations of efficiency of boilers be determined as we would undertake to determine limitations of efficiency of the operation of any type of apparatus, if we care to undertake improvement. These studies are landmarks and consequently evidence of what we may aspire to in attempting to prove our apparatus in this particular line.

Now as to the actual testing of fuel. Unlike the testing of boilers, it is difficult to find out the relative value of fuels. In studying the relative value it is, of course, necessary to find a unit of comparison. Some would advocate, as we have on record, the ultimate analysis of the fuels.

Again, we can take the experience of the chemist, using the fuel calorimeter. He finds, by the application of small quantities of fuel, that there is a different heat value. We have two separate tabulations of relative values of fuels so called, based either on the calorimetric determination or on the chemical analysis. Now the question which engineers will ask sooner or later is, does this relative value of one coal with another represent to us its relative value in the actual application, say, in the generation of steam? Unfortunately, I must say, in view of experiences in the past few years, the relative value as determined by analysis or fuel calorimeters rarely applies to steam boilers, and for many reasons, some of which have been clearly expounded by Prof. Breckenridge. Other disturbing elements appear to be incapable of any rationality. The problem is, what is the value of this fuel and what is the value of that fuel under this boiler? We wish to know what it costs us to generate a certain amount of steam with this and that fuel. In the determination of the relative value of the fuels it must be clearly recognized that the rate with which the fuel is burned under a given boiler is very important in determining the value of that fuel as to the amount of water that it will evaporate. If attempts to compare one fuel with another as a steam-making fuel are to be made, it must be with the full appreciation that a *series* of boiler trials must be made on that one boiler with a certain kind of fuel at different rates of firing. A "curve of evaporation" will give the value more nearly than any of the arbitrary speculations upon the chemical composition or any other process that seems possible.

The manner of conducting boiler trials so as to establish the "curve of evaporation" for a given fuel under a given size and type of boiler is shown in some detail in the JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS of August, 1897, in a paper presented at that time to the Society by the speaker.

Prof. Kerr—Some two or three years ago I had the pleasure of a talk with Prof. Breckenridge in regard to plans he was going to put into operation on a new Central Station at the University of Illinois, and from the variety of boiler settings which he has shown us this evening it would seem that he has been able to solidify most of his schemes. I was talking with our fireman at the Institute not long ago, in regard to the question of having different boilers and different settings, and he said he would rather have boilers all alike; that they would run together better. I expect that is a common opinion among firemen. I want to commend Prof. Breckenridge for putting in so many different types of boilers for educational purposes, and I think he deserves encouragement in this line of work.

Some time ago one of the reporters got me under his influence and made me say there was not a practical smoke consumer in the market. Not long after that we got a smoke notice, so we had to set out to show the reason why we made so much black smoke, and we have begun to try smoke consumers. One we have been trying is the oldest practice of all; that is a plain steam jet. It will do some good under some circumstances. We made comparative tests on the same grade of coal with boilers running under the same circumstances as to capacity, etc. The fireman interested in the success of the smoke consumer tried all his tests and he made smoke. Then we put our regular fireman to work on the furnaces without the use of the smoke consumer. He started in with the intention of laying the other firemen out. The results showed that the furnace boilers, with the use of the smoke consumer, gave an evaporation per pound of coal at about 6.4 pounds of steam per pound of coal. Without the use of the smoke consumer we got 7.6 pounds. There was a difference of about 18 or 20 per cent in favor of making smoke, which we did. We have a load on our shoulders in what we have undertaken to do, and we will probably try all the consumer devices that there are on the market before we get through. I have one which we are going to try next, and by the time Mr. Guthrie gets his perfected, I think we will be ready to try that. It is a pretty broad subject—the question of consumption of fuel—to get the best results. I have noticed results of tests in which this particular thing was called up, not only our own but those of others, in which different expert firemen used the same fuel and tested the different methods of firing for efficient smoke consumption, as well as capacity, and the fireman who made the most smoke got the highest results.

So long as conditions like that are obtainable we are going to encounter the strongest kind of opposition to do away with smoke. It is a question of dollars, and so long as that is behind it, it is going to be difficult to make a solution of that question, no matter how desirable.

Mr. Guthrie—I do not see why it is that his chimney smoked (the Armour Institute), when one with the same smoke device did not smoke; that is, omitting the steam jet. The Tacoma building is almost absolutely without objection, and that is run entirely by the use of the McGinnis drop door. Is it not on account of the difference in construction of the boiler that you are using the water tube? The gas gets away from the fire before the air gets to it, but at the Tacoma the smoke is almost entirely prevented.

Mr. Rice—Some years ago I had occasion to notice a furnace where they produced a high efficiency with certain Illinois coal from the "third vein" district, with a device designed by the late Mr. Higginson of the A., T. & S. F. R. R. In fact, higher evaporative results were produced than under similar boilers elsewhere, but with plain settings. I think that the smokeless condition was in part due to the good firing; they had a very excellent fireman there, but it was undoubtedly helped by the device, which essentially consists of a fire wall arranged to keep the flames from direct contact with the boiler, and of an arrangement for regulating the air supply.

There is one point that has not been touched on in regard to tests that I would like to have brought out and discussed; that is, the question of moisture in coal. I have had occasion to use a good many Illinois coals, and have found large but varying amounts of moisture in them. It would seem that one reason for different results of tests on the same coal by different parties is the different allowances made for moisture. I notice on the chart before us mention is made of "dry coal." I do not know what "dry coal" means. I am interested in the mining of coal, and find that its moisture is a very uncertain thing, and yet not so uncertain as the attempted determination of the percentage of moisture. So it appears to me that the truer measure in evaporation tests of coals would be to take the evaporation efficiency as the coals is furnished commercially, and not attempt to reduce results to the purely theoretical basis of dry coal. Further, I would not consider a test as standard unless the coal is used within a short period from the time it is taken out of the mine. With the lignite coals obtained further west, it would lead to absurd results to attempt to reduce their evaporative efficiency to a basis of dry coal, as these coals have as high as 30 or 35 per cent of moisture.

The difficulty appears to be to draw a line between moisture or water held mechanically in the pores of the coal and that entering into the structure.

Several years ago I had occasion to observe the results of two tests on the same coal by different parties. In one case the method of obtaining the basis of dry coal was to put a certain quantity on top of the furnace and let it dry out, and then figure the percentage of dry coal in that way. In the other case the sample of coal was placed over an extension furnace and heated nearly to the point of driving off the lighter volatile gases.

The results were astonishingly different. In the first case they obtained a moisture result of 3 per cent, and in the other case between 6 and 7 per cent. This gave very different efficiencies for the coal in the two tests. Hence it has occurred to me that there has been too little attention paid to this feature in comparing results of tests of our western coals. With eastern coal, and particularly anthracites, in which the percentage of moisture is very low, the matter is of much less importance.

Prof. Breckenridge—One or two things have been brought out by the gentlemen discussing this question.

In the first place, do not take these tests as representing model tests, but simply what we have been able to do at the University of Illinois with our facilities. I feel that the facilities for making these tests are not adequate. The results include the question of the economical performance of the furnace and boiler combined. The econometer which has been brought out recently will be a help in the further study of furnace conditions. I do not think we appreciate enough the value of a good draft for burning Illinois coal. A larger part of the tests were made in our old plant, in which the draught was extremely poor. We had not to exceed three-eighths inch of water. It is almost impossible to get good results with such a small draft. Enough attention is not paid to the question of draft in the burning of this coal.

There should be from one inch to one and one-eighth inches. Whether we can afford to go into the question of determination of the most economical conditions under which Illinois coals can be burned, I am sure I do not know. It costs lots of money, it takes lots of time. Are not the industrial conditions of the State of Illinois of enough importance to the engineers of the State that it is worth while to investigate some features of the economical performance of steam boilers? We are burning $20,000,000 worth of Illinois coal per year, and it seems to me that a great deal of that, at least some of it, might be saved if we would do it better. I think the chance for study of furnace conditions and furnace operations in connection with boiler plants affords one of the most promising sources of saving in power plant to-day. I think there is no doubt about it. We lack apparatus and facilities for making thorough investigations. We are beginning to see how these investigations must be made and to realize their importance. With the facilities we now have we ought to be able to do something, but we need an appropriation of $100,000 for special investigations in many industrial lines. However, the State has been particularly generous with the University of Illinois; but I do feel that the engineers of the State do not realize the chance for experimental investigation which exist at the College of Engineering in our State, and that there are engineers there who would gladly do a great deal more if they had the facilities for doing it.

Mr. Weinshank—I have been for the last four or five years trying to prevent smoke, and have succeeded in a number of places. The best I could get was 20 pounds of air or 325 to 350 cubic feet per pound of coal.

Mr. J. J. Merrill—The plant that Mr. Bement refers to is, I think, one of twenty boilers which were formerly in service. We discontinued the use of nine of them, with a reduction of 75 tons of coal per day for the same boiler load. We accomplished such result by analyzing the gases and having intelligent furnace management.

Speaking of the burning of a large amount of coal per square foot of grate, we have another plant equipped with chain grate stokers, and burn 50 pounds per square foot. This is a new plant, and I intend to have it tested very soon as to its performance. I can only say that, for the same amount of work, there is a reduction in coal of 55 tons per day, as compared with the practice with the old plant, which had about 30 per cent more heating surface. With our Chicago plant with twenty-seven boilers, some years ago, I found twenty boilers the most economical number to keep in service. Owing, however, to difficulty in securing competent immediate supervision, the number in use increased to twenty-six, but with a new man in charge we are able to again operate with twenty boilers. The saving thereby is 50 to 60 tons per day, the boiler load being the same.

In reference to forcing fires, Mr. Bement and myself have had a hand-fired furnace so worked that 72 pounds of coal was burned per square foot per hour.

I agree with Prof. Breckenridge about the advantage of a strong draft. With our new stoker plant mentioned we can get 0.7 inch draft over the fire, but we use about 0.4 inch.

We get the results referred to by studying the condition of combustion, and having, as far as possible, a competent man in immediate charge.

Mr. Bement—This statement about burning 72 pounds of coal per square foot of grate per hour requires an explanation. My idea was to ascertain what could be accomplished by manipulating the fire. The furnace is provided with a Dorance shaking grate of 46.6 square feet; the draft over the fire was 0.4 of an inch of water; coal, Illinois screenings and slack. Two men were detailed for the work and each provided with a light rake. They coaled the fire light and very often, using the rake to disintegrate the surface of the fire before each coaling, and shook the grate often enough to discharge the accumulating ash, but not enough to shake the fire through. The amount of coal burned per hour per square foot was 72.2. The gases in one sample, gathered uniformly over the period, were CO_2 11.2; CO 0.2. This was, of course, a supreme effort, and for one hour only, but could have been continued indefinitely had a fresh set of men been provided for each hour. A strong draft will make better combustion always than will a mild one. This is illustrated by a locomotive, which can easily be worked to make 15 or 16 per cent CO_2, with complete combustion and no smoke; but with the experiment in question there was no high draft pressure, and consequently to get enough air in contact with the fire, its resistance was reduced by means of the rake, and when oxygen comes in contact with red-hot carbon, it is not necessary that it comes with a high-draft pressure.

Prof. Chamberlain of Lewis Institute—In the discussion that has been brought up we shall always take pleasure in knowing that we have a good tabular statement of tests made on Illinois coals, and that, perhaps, is the greatest satisfaction we will get out of it. We are not all going to read the paper and study it carefully excepting as we have especial interest in knowing what can be done or what has been done, but it certainly is an act of kindness to tabulate results and put them in such form that they may be available for use and for ready reference.

In connection with some of the discussion that has been brought out I am going to ask Prof. Breckenridge as to the observance of smoke in conjunction with the tests, whether or not it was an observable fact that better economy was gotten out of the same coal when the chimney was giving forth great, dense smoke? It would seem reasonable to suppose that the absence of smoke was some indication of better combustion, and certainly if we had good combustion we ought to be getting better efficiency from our coal. I presume that there is scarcely anyone in Chicago who has been responsible for the production of power but has in some way come in contact with the smoke inspector, and I would say that in our experience, in the plant I am connected with, we attempted to solve the smoke problem for our plant, and were to a degree successful. We at least escaped the smoke inspector. It may be of interest to know that the cost of our coal for the years 1896 and 1897 was about one-sixth greater than it has been during the last year, and we have increased our power (which, of course, is only one feature of the use of steam) 100 per cent, and we have increased the heating requirements about 20 per cent, which, of course, is the final measure; that is, the dollars and cents is the final measure of the efficiency of the coal.

Mr. Wickhorst of C., B. & Q. R. R.—I would like to emphasize the idea that Mr. Bement has brought out, namely, that a boiler test consists of two distinct tests.

1st—The consideration of the furnace itself.

2nd—The consideration of the boiler proper.

The furnace is a piece of chemical apparatus for the purpose of oxidizing carbon, volatile coal gases, etc. To determine the efficiency of the furnace, it is necessary to make analyses of the products of combustion to determine whether combustion is complete, without at the same time having an unnecessary excess of air. Also it is necessary to study whether the mixture of the gases and air is satisfactory. The furnace test, therefore, would require the determination in the waste gases, ordinarily, of carbon dioxide, carbon monoxide and oxygen.

The boiler proper is a piece of apparatus for absorbing the heat units from the products of combustion and allowing them to escape at the lowest temperature practicable. The test of the boiler, therefore, consists in its ability to evaporate water. Whenever it is desired to improve the efficiency of a boiler, as a whole, it is necessary, therefore, to first study the furnace to determine that combustion is satisfactory, then after this is done, to make evaporation tests with good combustion conditions. It is my duty once in a while to make tests of various kinds, in connection with locomotives. Mr. Bement is getting for us some gas analysis apparatus which we expect to install in our C., B. & Q. test car as a part of its permanent equipment. We are doing this with a view of studying locomotives as combustion machines, and will probably do this independent of boiler entirely.

Mr. Tratman—Some people have an idea that all you have to do to prevent smoke and to economize in fuel is to put in an automatic stoker. I was in a large power plant a few weeks ago, and on remarking upon the bare appearance of the boiler fronts I was told they had just taken out automatic stokers from the entire battery, as they could not keep up the steam with them and they were not efficient. They found it cheaper and better, on the whole, to take these out altogether and hire a gang of men and "throw away smoke at the top of the stack."

Probably the stokers used were not suited to the plant, or were not properly handled, but instead of trying to find a better style, the company simply dropped them and resorted to hand firing.

Prof. Breckenridge—That is a good illustration of what people do when they do not know what they are doing.

Mr. W. L. Abbott—On the line under the discussion of whether a boiler gives better efficiency when fired at a high or low rate, I wish to say that at one of our plants we have recently conducted a series of tests on various Illinois coals. The tests were made for the purpose of determining the most efficient coal—that is, the most economical coal—and also the one which would make the most steam in a boiler. These tests were made on a 500 H. P. boiler. Some coals produced about 350 H. P., and others up as high as 700 H. P. It was very interesting to note that the efficiency of the boiler was in almost direct proportion to the amount of steam which could be made. That is, the higher we could force the boiler, the greater would be its efficiency. It would run down as low as 45 per cent on the weaker coals and up as high as (not 80) 72 per cent on the better ones. The Professor called me down for saying 80 per cent, and I notice the highest point in his curve is only 79½ per cent. I was in error there.

Will washing coal fix it so it won't smoke? Some say that washed coal can be burned in furnaces in houses without smoke. That was told to me, and I recommended it for a certain place, and the coal and the one who recommended it were voted a nuisance. I would like to have the Professor explain how washing a lot of clay or iron out of the coal will make it smokeless.

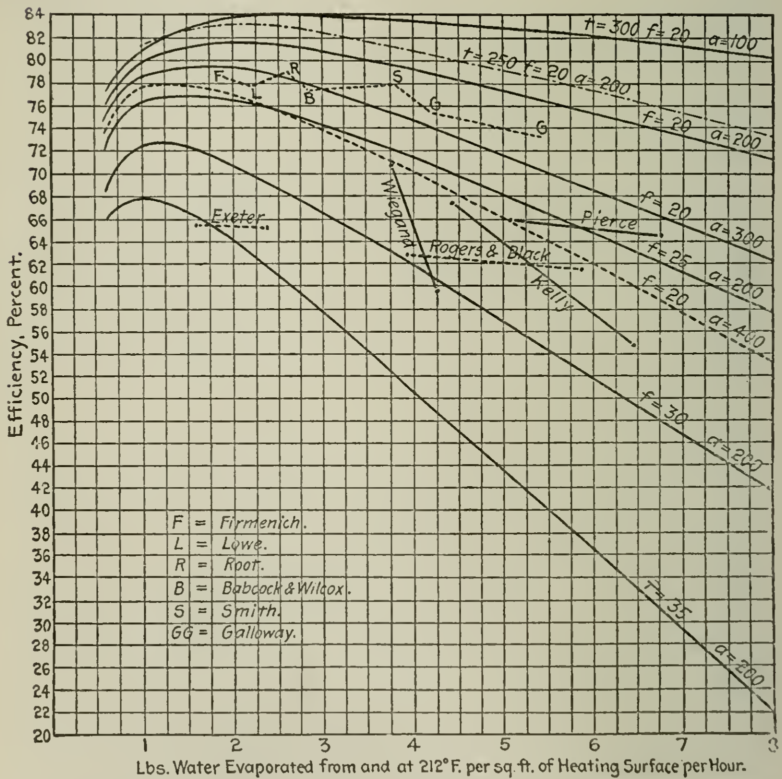

FIG. 11. CURVES OF CALCULATED EFFICIENCIES FOR DIFFERENT RATES OF DRIVING, for $K = 14,800$, $R = 0.1$, $t = 300$ (except one curve, $t = 250$) $f = 20$ to 35, $a = 100$ to 400.

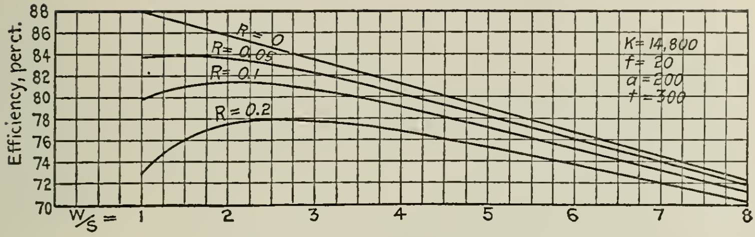

FIG. 12. **EFFECT OF RADIATION UPON EFFICIENCY.**

APPENDIX — PROF. BRECKENRIDGE.

Replying to the question of Professor Chamberlain, I would say that dense volumes of black smoke do not represent the large loss that many suppose. During two boiler tests, in the first trial much smoke was made; in the second no smoke was made, it being prevented by steam jets delivering air at the bridge wall. The steam jets required about 8 per cent of the steam generated. It required about 5 per cent more coal for the same work done by the boiler, leaving approximately 3 per cent saving due to preventing the smoke. In the ordinary small hand-fired boiler it costs money to prevent smoke.

In reply to Mr. Abbott's question, I can only say that I have used Carterville washed nut coal in my hot water house heating boiler for two winters and it has not made any appreciable amount of smoke. The absence of sulphur and clinkers, whereby the air has a free flow through the coal bed, is, I believe, reason enough for this result. I have not been able to prevent considerable smoke with various other grades of coal. I think here again what is needed is a good draft, uniformity in size of coal used, and not too much indirect heating surface in the boiler; it is, or should be, the fire pot surface that does most of the work at comparatively low temperatures.

Referring to the diagrams Figs. 11 and 12, which have been reproduced from "Steam Boiler Economy," by William Kent, we are able to clearly see the efficiency of a boiler due to different rates of driving. This subject has been carefully discussed in the volume referred to, and numerous other diagrams are also presented by Mr. Kent, several of which were shown on the screen at the meeting of the Society, but which have not been reproduced here.

The general formula for the efficiency of a boiler and furnace combined is given by Kent as follows:—*

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*See "Steam Boiler Economy"—Wm. Kent, p. 219.

$$\frac{E\,a}{E\,p} = \frac{K - t\,c\,f}{K\,(1 + R\,\frac{S}{W}} - \frac{966\,a\,c^2\,f^2}{K\,(K - tcf)}\,\frac{W}{S}$$

in which

Ea = Actual evaporation per pound of fuel.
Ep = Possible evaporation per pound of fuel.
K = Heating value of fuel per pound of combustible.
$\frac{W}{S}$ = Evaporation per sq. ft. of heating surface per hour.
t = Excess of the temperature of the water in boiler above the atmospheric temperature.
c = Specific heat of escaping gases considered a constant.
f = Weight of gases per lb. of fuel.
R = Radiation per square foot of heating surface per hour.
W = Water actually evaporated, pounds per hour, reduced to equivalent evaporation from and at 212° per hour.
S = Area of heating surface in sq. ft.
a = (What the writer would call "Kent's coefficient")* is a coefficient of resistance to transmission of heat and of other elements of inefficiency—most easily expressed by $a = \frac{A\,(T - t)}{c\,f}$, the numerical value of which lies between a = 100 and a = 400.

This expression may be much simplified by making several permissible assumptions and assigning usual values to others.

In Fig. 11 K = 14800; R = 0.1; t = 300; f = 20 to 35; a = 100 to 400.

In addition to the curves plotted with these assumptions, there are shown some of the highest results obtained in actual tests by various types of boilers.

For best practice it is evident that *a* should lie somewhere between 200 and 300.

The importance of a correct air supply is seen by noting the rapid lowering of the efficiency by a rather small increase in the value of *f*.

In Fig. 12 it is seen how that with low rates of driving, i. e., $\frac{W}{S} = 1$ to 3, the radiation losses may seriously affect the efficiency, while at higher rates this loss is not of such consequence.

After all it would certainly seem that the greatest care should be observed in the operation of furnaces, and that less importance should be attached to the many and varied forms of boilers, but more importance attached to careful setting draft, and operation of the standard types.

Table No. 1.
Tests with Horizontal Tubular Boilers.

BOILER TESTS WITH ILLINOIS COALS,

Made at the
University of Illinois, by the Mechanical Engineering Department.

WESTERN SOCIETY OF ENGINEERS.
Vol. VI. No. 3.—PLATE 1.
Breckenridge—Boiler Tests with Illinois Coals.

Nº FOR REFERENCE	KIND AND LOCATION OF BOILER	DATE OF TEST	KIND OF FUEL	DURATION OF TEST HOURS	GRATE AREA IN SQUARE FEET	WATER HEATING SURFACE SQUARE FEET	LEAST FLUE AREA SQUARE FEET	AREA OF CHIMNEY SQUARE FEET	HEIGHT OF CHIMNEY ABOVE GRATE FEET	WATER HEATING SURFACE / GRATE AREA	GRATE AREA / LEAST FLUE AREA	FORCE OF DRAFT IN INCHES OF WATER	STEAM PRESSURE IN BOILER BY GAUGE	TEMPERATURES FAH.				DRY COAL CONSUMED PER SQ FT OF GRATE PER HOUR	PER CENT OF REFUSE DRY	EVAPORATION FROM AND AT 212° FAH			H. P. PER BUILDERS RATING	H. P. ON BASIS OF 34½ POUNDS EVAPORATED FROM AND AT 212	
														EXTERNAL AIR	STEAM	ESCAPING GASES	FEED WATER			PER POUND OF DRY COAL	PER POUND OF COMBUSTIBLE	PER SQ. FT. HEAT. SURF. PER HR.			
1	Nº 2 HORIZONTAL TUBULAR U of I SHOPS	4-16-94	BLOOMINGTON	812	1875	533	1.66	56	52	1:035	11.3:1	.23	687	7715	314.7	553	54.7	13.36	12 7	6 06	6.95	3.07	40	45.44	
2		4-30-94	,,	8.95	18 75	533	166	5.6	52	1:035	113:1	.27	70.3	837	316 0	447	60.7	9.00	170	5.50	7.81	1.74	40	35.00	
3		5-5-94	,,	9.16	1875	533	166	56	52	1:035	113 1	.28	72 2	69.1	317.6	516	58.0	12 00	190	5.35	7.88	2.26	40	4600	
4		5-7-94	,,	9 0	1875	533	166	56	52	1:035	11.3:1	.24	70.6	680	3163	432	560	6 80	15.0	5.20	740	354	40	21.00	
5		5-8-94	,,	8.95	1875	533	1.66	5.6	52	1:035	11.3:1	.20	68.4	70.4	314.5	501	564	11.00	16.0	5.50	7.87	2.12	40	4300	
6		11-20-94		5 0	1875	533	166	56	52	1:035	113:1	.41	71 0	51.0	3166	454	540	9 34		5 80	7.43	1 90	40	2933	
7		11-22-94		5.0	1875	533	166	56	52	1.035	113:1	.20	71.2	50.85	316.7	520	542	13 90	12 8	6.06	6 86	2.60	40	4585	
8		1-28-95		11.0	18.75	533	166	56	52	1 035	113:1	.30	69.7		3155	61 8.6	51.0	15.20	15.3	5.49	6.48	2.94	40	4546	
9		1-29-95		11.5	1875	533	166	56	52	1.035	11.3:1	.30	61.4		308.4	584	510	11.80	166	6.89	8.26	2.89	40	4460	
10		1-30-95		11.33	18.75.	533	1.66	56	52	1:035	11.3:1	.28	68 8		314 8	655	511	13 47	16.3	6 04	7.21	2 86	40	4410	
11		1-31-95		11.5	18.75	533	1.66	5.6	52	1:035	11.3:1	30	70.7		31634	655	506	13.20	160	637	7.61	3.00	40	4600	
12		2-1-95		11.16	18.75	533	166	56	52	1:035	113:1	.23	70.5		316.16	623	499	13 20	15.5	6 10	7.23	2.77	40	42.80	
13		2-2-95		10.0	1875	533	166	56	52	1:035	11.3:1	.30	69.0		315.	611	507	12 20	18 4	7 71	9.44	3.33	40	51.00	
14		4-1-95		10.0	1875	533	1.66	56	52	1:035	113:1	.30	69.0		315	611	50.7	12.20	18.0	6.42	9.44	3.30	40	5100	
15		4-3-95		10.5	18.75	533	166	56	52	1:035	11.3:1	.20	580		305.3	520	52.0	10.20	180	5 92	7.25	1.68	40	3270	
16		4-4-95		105	1875	533	166	5.6	52	1:035	113:1	20	61.0		308.	540	540	7.00	210	6.94	8.98	1.86	40	2870	
17		4-5-95		10.5	1875	533	166	56	52	1:035	11.3:1	21	70.0		315.9	527	557	860	190	7.92	980	2.38	40	3690	
18		4-6-95		10.25	1875	533	166	5.6	52	1.035	113:1	.20	62 0		308.9	533	530	11.60	120	6.70	7.87	270	40	445	
19		4-9-95		10.0	18.75	533	166	56	52	1:035	113:1	.20	60.1		307.2	680	535	15.36	18.2	5.90	7.25	320	40	49.28	
20		4-10-95		10.3	1875	533	166	5.6	52	1:035	11.3:1	.20	60.1		307.2	693	530	12.00	163	5.79	6.92	2 63	40	40.67	
21		4-11-95		10.5	1875	533	166	56	52	1:035	113:1	.20	59.0		306.2	686	542	12.92	147	6.53	7.66	2.97	40	4587	
22		4-12-95		10.0	1875	533	166	5.6	52	1:035	11.3:1	.20	590		306.2	693	540	13.06	17.2	6.30	763	2.89	40	447	
23		4-13-95		10.0	18.75	533	166	56	52	1:035	11.3:1	.20	57.0		304.3	729	540	13 57	172	6 62	798	315	40	48.75	
24		6-11-96	ODIN PEA	9.5	18.75	533	166	56	52	1:035	113:1	.18	67 6	75.5	313.8	514	60.7	8.35	13.9	5.59	6.52	1.76	40	2530	
25		6-12-96	,,	9.5	1875	533	166	5.6	52	1.035	11.3:1	16	68 1	63.5	314.2	511	61 5	8 88	13.7	5.03	585	1 69	40	2430	
26		6-13-96	"	9.5	18.75	533	166	56	52	1 035	11.3:1	.15	67.6	740	313.8	500	61 5	7.97	135	5.57	647	168	40	2420	
27		6-15-96	DU QUOIN LUMP	9 0	1875	533	166	56	52	1:035	113:1	.19	690	799	315.0	516	620	741	10.5	604	6.77	1.69	40	2430	

Table No. 1—Continued.
Tests with Horizontal Tubular Boilers.

BOILER TESTS WITH ILLINOIS COALS,

Made at the
University of Illinois by the Mechanical Engineering Department.

Western Society of Engineers.
Vol. VI. No. 3.—Plate 2.
Breckenridge—Boiler Tests with Illinois Coals.

No. for Reference	Kind and Location of Boiler	Date of Test	Kind of Fuel	Duration of Test Hours	Grate Area in Square Feet	Water Heating Surface Square Feet	Least Flue Area Square Feet	Area of Chimney Square Feet	Height of Chimney above Grate Feet	Water Heating Surface / Grate Area	Grate Area / Least Flue Area	Force of Draft in Inches of Water	Steam Pressure in Boiler by Gauge	Temperatures Fah.				Dry Coal Consumed per Sq. Ft. of Grate per Hour	Per Cent of Refuse Dry	Evaporation from and at 212° Fah.			H. P. per Builders Rating	H. P. on Basis of 34½ Pounds Evaporated from and at 212°
														External Air	Steam	Escaping Gases	Feed Water			Per Pound of Dry Coal	Per Pound of Combustible	Per Sq. Ft. Heat Sur. per Hr.		
28	No. 2 Horizontal Tubular U. of I. Shops.	6-16-96	Du Quoin Lump	95	1975	533	166	56	52	1: 035	11.3: 1	17	69	79.2	315.	490	611	7.33	9.6	626	6.94	1.73	40	25.0
29		2-13-97	Sangamon Lump	80	18.75	533	166	56	52	1: .035	113:1	.20	737	44.4	318.8	633	490	18.7	12.2	7.23	8 27	3 63	40	52 2
30		2-19-97	"	81	18.25	533	166	56	52	1· 0248	7.9: 1	.20	761	396	3206	498	470	20.1	13.6	5.97	6 96	3.21	40	461
31		2-20-97	"	9.5	1825	533	166	56	52	1· 0248	7.9.1	13	751	507	319.9	4871	480	168	117	6 46	7.35	2 92	40	420
32		2-26-97	Paradise Lump	80	13.25	533	1,66	56	52	1:0248	7.9:1	.48	83.0	174	325.9	5660	460	213	86	6.89	7.57	3.93	40	564
33		2-27-97	"	80	1325	533	166	5.6	52	1.0248	7.9·1	.33	81.2	18.0	3245	632.0	490	17.1	9.5	726	8.05	332	40	47.6
34		3-3-97	Sangamon Lump	8.42	13 25	533	166	56	52	1:0248	7.9:1	.69	75.8	27.0	320.4	557	48.0	182	11.6	7.58	8.61	3.70	40	53 0
35		3-5-97	Mt. Olive Lump	80	13.25	533	166	5.6	52	1·0248	7:9:1	35	75.8	41.0	320.4	533	460	173	7.5	6.72	731	3.12	40	447
36		3-6-94	"	8.0	13.25	533	166	5.6	52	1:0248	79:1	.59	757	324	3203	601	48.0	217	7.3	712	7.72	415	40	596
37		3-25-97	Athens Lump	767	13.25	533	166	56	52	1: 0248	79:1	.17	78.4	38.5	3225	520	48.0	16.7	9.4	6.25	692	2.79	40	40.0
38		4-8-97	"	8.0	13.25	533	1.66	5 6	52	1:0248	79:1	.22	76.7	43.1	321.1	527	532	16.0	6.9	676	7.27	2.93	40	421
39	No. 3 H. T. U. of I. Shops	2-10-96		8016	18.00	525	2	3.2	52	1: 0340	9:1	.29	83 2	371	326	214.4	51.2	18.6	10.9	6.55	7.42	4.18	40	63.7
40	No. 1 Horizontal Tubular U. of I. Shops	9-17-95	Du Quoin Lump	80	16.66	547	2.09	7	52	1:0305	794:1	.21	62.0	880	308.9	477	643	8.6		5.116	5.87	1:34	40	212
41		9-18-95	"	8.0	1666	549	2.09	7	52	1:0305	7.94:1	.21	61.0	89.0	301.	474	670	77		5462	6.20	1.30	40	204
42		10-3-95		80	1666	547	2 09	7	52	1·0305	794:1	.31	63.4	70.0	310.2	619	61.8	13.05		531	6 50	2.01	40	345
43		10-4-95		8.0	1666	547	2.09	7	52	1:0305	794:1	.22	66.0	676	312.4	543	613	13.2		5.88	7.05	2 39	40	37.9
44		10-6-96	Odin Pea	80	16 66	547	2 09	7	52	1:0305	7.94:1	20	73.0	62.0	318.3	494	526	12.4	16	6.13	7.32	2.35	40	35.5
45	No. 2 & 3 H. T. Urbana & Cham. Water Works	11-26-95	Muncie Slack	10:0	22.5 Each	1060 Each	3.8 Each	125	75	1· 021	5.91:1	43	748	242	319.7	301	140	13.62	19	6.07	7.50	2.89	170	1078
46	No. 3 & 4 H. T. Urbana & Cham. Water Works	1-16-97	Odin Pea	8.0	45	2260	8	12.5	75	1: 0199	56:1	.40	75.06	354	319.9	377	131.5	9.89	163	6.40	782	1.26	188	828
47		1-23-97	"	80	45	2260	8	12.5	75	1:.0199	5.6:1	.38	7136	206	316 8	375	132 2	10.6	16.11	6.04	722	127	188	83.6
48		3-29-94	"	8.0	45	2260	8	12.5	75	1:.0199	56:1	.40	66.0	55.0	312 4	322	120.2	10.4	153	6.40	760	132	188	869
49	No. 4 H. T. U. of I. Cent. Heat Plant	2-27-95	Du Quoin Lump	90	30	1010	433	23.75	95	1:.01029	7.11:1	.25	65.6	49.7	312.1	519	48.4	15.2	11.08	738	8.28	3.99	100	1174
50		3-6-95	Odin Lump	925	30	1010	433	23.75	95	1:01029	7.11:1	.25	6766	354	3138	531	500	1514	15.31	699	822	377	100	1104
51		3-10-96		95	30	1010	433	23.75	95	1:01029	7.11:1	.18	7113	450	316.6	589	548	28.36	975	687	7.6	5.44	100	1596
52	No. 1 U. V. C. Ice & Cold Storage Co.	2-24-26-96	Nut & Slack	48	22.5	870		452	60	1: 02583		.40	77.0	44.4	321.4	6140	156.2	17.0	19.0	5.40		2.37	60	6014
53		3-3-5-96	Pea	42.	22.5	870		452	60	1:0258		.42	773	40.5	321.8	6410	1730	15.75	10.74	5.88		239	60	6037
54		98	Du Quoin Slack	8	225	870		4.52	60	1: 0258		.32	93.0	671	333	5350	1777	150	1750	709	864	2 90	60	7410

Table No. 2.
Tests with Water Tube Boilers.

BOILER TESTS WITH ILLINOIS COALS,
Made at the
University of Illinois by the Mechanical Engineering Department.

Western Society of Engineers.
Vol. VI. No. 3.—Plate 3.
Breckenridge—Boiler Tests with Illinois Coals.

Nº for Reference	Kind and Location of Boiler	Date of Test	Kind of Fuel	Duration of Test Hours	Grate Area in Square Feet	Water Heating Surface Square Feet	Least Flue Area Square Feet	Area of Chimney Square Feet	Height of Chimney above Grate Feet	Water Heating Surface / Grate Area	Grate Area / Least Flue Area	Force of Draft in Inches of Water	Steam Pressure in Boiler by Gauge	Temperatures Fah				Dry Coal Consumed per Sq Ft of Grate per Hour	Per Cent of Refuse Dry	Evaporation from and at 212° Fah			H P per Builders Rating	H P on basis of 34.5 Pounds Evaporated from and at 212
														External Air	Steam	Escaping Gases	Feed Water			Per Pound of Dry Coal	Per Pound of Combustible	Per Sq Ft Heat Sur per Hr		
101	Nº 3. STIRLING U. of I. CENT. HEAT PLANT.	11-14-96	ODIN LUMP	8	135	525	321	12.6	95	1:0257	420'1	.23	845	544	3269	506	2154	2160		616	700	3422	50	521
102		11-21-96	..	8	13.5	525	3.21	12.6	95	1.0257	420'1	.23	791	41.0	3229	567	2184	22.60	137	642	746	3724	50	567
103		11-27-96	..	7	135	525	321	12 6	95	1'0257	420.1	.24	81.0	29.	324.4	550	221.0	2196	129	6.02	694	3398	50	51.7
104		12-22-96	..	8	135	525	3.21	12.6	95	1'0257	420'1	25	85.4	42	327.7	573	2190	20.90	14.0	660	772	3543	50	539
105		12-23-96	..	8	135	525	321	12.6	95	1'0257	420'1	25	83.4	34	326.2	557	216.0	1980	145	6.68	786	3395	50	517
106		12-24-96	..	8	13.5	525	321	12 6	95	1'0257	420'1	.18	83.1	29	325.9	500	219.7	15.70	168	706	855	2861	50	435
107		12-26-96	..	792	135	525	3.21	12.6	95	1:0257	420'1	36	777	35	321.9	552	2165	1710	127	6.94	8.00	3059	50	466
108	Nº 5. BABCOCK AND WILCOX U. of I. CENT. HEAT PLANT	12-11-94	BLOOMINGTON LUMP	6.0	51	2450	1025	12.6	95	1'0208	5 ' 1	.30	536		301.1		53.6	2480		530	6.26	2 60	220	165.2
109		1-12-95	DU QUOIN LUMP	10	51	2450	10.25	12.6	95	1:0208	5:1	35	710	4	316.6	497	50.8	21.20		659	769	2.83	220	2062
110		1-16-95	MEAUTIC NUT	10	51	2450	1025	12.6	95	1'0208	5:1	30	59.5	32	3067	485	49.6	1874		488	5.92	1.850	220	1354
111		1-19-95	MOWEAQUA LUMP	10	51	2450	10 25	126	95	1'0208	5:1	30	550	35	3024	489	515	2080		536	627	2 25	220	1645
112		1-23-95	ODIN LUMP	10	51	2450	10 25	12 6	95	1'0208	5:1	30	675	18	313 7	471	500	20.30		591	639	2.30	220	182.5
113		1-26-95	..	10	51	2450	10 25	12 6	95	1:0208	5'1	30	693	13	315.2	424	510	12 70		6 23	7.11	1610	220	1171
114		2-23-95	"	9.15	51	2450	10.25	126	95	1.0208	5'1	.35	681	37	314.2	519	484	22 88		598	688	2.680	220	1354
115		2-27-95	DU QUOIN LUMP	9.	51	2450	1025	12.6	95	1'0208	5'1	25	656	48	312.1	533	48.9	1780		6.60	739	2.350	220	1734
116		3-6-95	ODIN LUMP	925	51	2450	10.25	12 6	95	1'0208	5'1	25	71.67	35	3171	465	500	1650		513	726	2.060	220	1503
117		10-25-95	"	80	51	2450	10.25	12.6	9.5	1:02.08	5:1	.34	68.5	43	3148	529	560	17.90		587	660	2.270	220	1551
118		12-29-96	"	80	51	2450	1025	12 6	95	1:0208	5'1	33	752	42	3199	491	510	2640	16.3	5.78	6 94	2.630	220	2258
119		1-15-97	"	82	51	2450	1025	12 6	95	1:0208	5.1	.39	571	34	304.4	470	50.0	2350	12 6	560	675	2.27	220	1950
120		1-16-97	"	80	51	2450	1025	12 6	95	1.0208	5:1	34	664	38	312.8		51.0	19.80	211	596	764	2 04	220	1750
121		6-26-97	"	775	51	2450	1025	12.6	95	1:0208	5'1	37	661		312.5	451	50.6	2400	14.5	5.42	641	2 25	220	1920
122	Nº 1. B & W. U&C EL&P Cº	6-13-94	PANA SLACK	10	54	2416	20	28	125	1'0223	54:1	23	957	90	334.8	494	59.0	1420		490	607	1.56	210	109.1
123		6-19-94	"	10	65	2416	155	28	125	1:0268	6.5 1	26	860	84	328	516	590	14.80		3.91	5.51	1.57	2.10	1097
124	Nº 2. B AND W. URBANA & CHAM EL & P Cº	6-11-94	PANA ½ SLACK ½ LUMP	105	38 5	2264	155	28	125	1'0170	2.48:1	.21	900	90	330.9	504	590	17.80	2.07	4.25	5.63	1.54	196	1010
125		6-12-94	PANA SLACK	100	51	2264	155	28	125	1 0225	3.67:1	.18	891	91	3300	480	59.3	13.50		571	7.47	1 73	196	1134
126		6-14-94	..	10	51	2264	155	28	125	1'0225	3.67:1	22	913	88	331.8	484	60.9	13 80		543	6.62	1.69	196	110.8
127		6-16-94	PANA SCREENINGS	10	51	2264	155	28	125	1:0225	3.67:1	20	95.9	85	334.8	464	60.5	1490		5.20	618	1 75	196	114.9
128		6-18-94	ODIN LUMP	10	51	2264	155	28	125	1'0225	3.67:1	21	98.5	71	336.6	482	59.5	13.20		573	651	1 97	196	129.0
129		6-29-94	PANA ½ LUMP ½ SLACK	1018	51	2264	155	28	125	1 0225	3 67:1	.32	950		334.3	529	60.7	2040		651	743	2 660	196	1963
130		12-9-96	ODIN LUMP	8	51	2264	155	28	125	1:0225	367:1	73	106.4	39	341.7	462	450	23.50	124	591	683	3135	196	2060
131		12-10-96	FAIRMOUNT SCREENINGS	8	51	2264	155	28	125	1 0225	367:1	74	108.2	40	342.8	487	540	3070	140	508	5.95	3506	196	2300

Table No. 2—Continued.
Tests with Water Tube Boilers.

BOILER TESTS WITH ILLINOIS COALS,
Made at the
University of Illinois by the Mechanical Engineering Department.

WESTERN SOCIETY OF ENGINEERS.
Vol. VI. No. 3.—PLATE 4.
Breckenridge—Boiler Tests with Illinois Coals.

Nº FOR REFERENCE	KIND AND LOCATION OF BOILER	DATE OF TEST	KIND OF FUEL	DURATION OF TEST HOURS	GRATE AREA IN SQUARE FEET	WATER HEATING SURFACE SQUARE FEET	LEAST FLUE AREA SQUARE FEET	AREA OF CHIMNEY SQUARE FEET	HEIGHT OF CHIMNEY ABOVE GRATE. FEET	WATER HEATING SURFACE / GRATE AREA	GRATE AREA / LEAST FLUE AREA	FORCE OF DRAFT IN INCHES OF WATER	STEAM PRESSURE IN BOILER BY GAUGE	TEMPERATURES FAH.				DRY COAL CONSUMED PER SQ FT OF GRATE PER HOUR	PER CENT OF REFUSE DRY	EVAPORATION FROM AND AT 212° FAH			H. P. PER BUILDERS RATING	H. P. ON BASIS OF 34½ POUNDS EVAPORATED FROM AND AT 212°
														EXTERNAL AIR	STEAM	ESCAPING GASES	FEED WATER			PER POUND OF DRY COAL	PER POUND OF COMBUSTIBLE	PER SQ FT HEAT SUR PER HR		
132	NATIONAL WATER TUBE BOILER U of I CENT HEAT PLANT	5-17-98	ODIN PEA	8	60.6	2513	16 74	2827	148	1:0137	36:1	22	105 5	66	341.1	491	55	13.51	165	5 41	6.47	1.77	2.50	1286
133		1-26-'99	"	6	60.7	2579	12.5	28.27	14 8	1:0235	4.85:1	.62	78.7	25.5	322.8	488.0	51.7	19.24	16 50	5.45	6.53	2.47	250	184.4
134	"	1-28-'99	"	8	"	"	"	"	"	"	"	.35	62 6	231	3095	517 0	49 2	20.05	15.70	5.06	6.00	2.58	"	178.1
135	"	2-16-'99	Junction Pea	8	"	"	"	"	"	"	"	.58	103.1	40.2	3383	506.7	49 0	16.75	9.36	6.87	7.58	2.71	"	2024
136	"	2-23-'99	Ridgely "	8	"	"	"	"	"	"	"	.60	111 0	27.2	344.5	508.0	48.0	18.80	.7.90	5.41	5.88	2.39	"	1791
137	"	2-25-99	" "	8	"	"	"	"	"	"	"	.74	109.6	34 4	343 7	474 0	49 9	18.85	11 34	5.34	6.02	2.43	"	1771
138	"	2-27-99	" "	8	"	"	"	"	"	"	"	.51	104.1	47 3	340.2	473.0	48.4	19.10	8.20	6.00	6.52	2 71	"	202.6
139	"	3-2-99	" "	8	"	"	"	"	"	"	"	.49	103 8	44.2	3400	532.0	49 5	18.80	8.90	5.80	6.36	2.56	"	191.6
140	"	3-4-'99	Dawson "	8	"	"	"	"	"	"	"	.31	94.3	35.3	333.3	455.5	50.6	17.36	12.54	4.74	5.42	1.94	"	144 8
141	"	3-11-99	" "	8	"	"	"	"	"	"	"	.51	107.9	62.9	342.6	541.6	51.1	15.85	13.90	5.78	6.56	2.11	"	157.4
142	"	3-16-99	" "	8	"	"	"	"	"	"	"	.30	110.8	38.1	344 3	511 0	54.6	14.60	11.40	6.00	6.76	2.07	"	154 4
143	"	3-17-'99	Ridgely "	8	"	"	"	"	"	"	"	.49	105.1	48.8	339.6	516.1	50.8	15.48	14.05	5.59	6.51	2.04	"	152.0
144	"	3-18-99	" "	8	"	"	"	"	"	"	"	.49	107.3	39.3	342.2	464 0	50.7	16.93	12.40	5.91	6.75	2.36	"	175.9
145	"	3-20.'99	Junction "	8	"	"	"	"	"	"	"	80	106.8	32 8	341.9	445.9	48.1	18.15	10.03	5.27	5.86	2.25	"	134 6
146	"	3-21-99	" "	8	"	"	"	"	"	"	"	.40	113.0	46.0	345.6	502.0	50.2	17.60	12.00	6.75	7.69	2.95	"	220 7
147	"	3-22-99	" "	5	"	"	"	"	"	"	"	.54	109.4	36.0	343.6	471.1	49.2	21.25	8.87	6.21	6.82	3.09	"	234 0
148	"	3-23-'99	Riverton "	8	"	"	"	"	"	"	"	.25	111.5	32.3	344.7	432.0	47.6	18.59	9.80	6.65	7.38	2.52	"	217 3
149	"	3-24-'99	" "	8	"	"	"	"	"	"	"	.60	109.6	37.8	343.7	491 7	48.9	20.01	8.87	5.77	6.33	2.72	"	203.1
150	"	3-25-99	" "	8	"	"	"	"	"	"	"	.40	111 6	35.8	344 9	462 0	48.5	19.04	12.10	5.83	6.63	2.61	"	195.2
151	BABCOCK & WILCOX U of I. Heat. Plant	3-3-00	Sangamon Pea	8	51	2450	10.25	12.6	150	1:021	5:1		108.8	36.4	342.9	603.0	51.5	34.73	16.5	6.8	6.5	4.9	220	292

ANALYSIS OF ILLINOIS COALS,
Made by the
Department of Applied Chemistry, University of Illinois.

Nº	KIND OF COAL	DATE OF ANALYSIS	MOISTURE	VOLATILE COMBUSTIBLE	FIXED CARBON	ASH	SULPHUR	CALORIMETER B.T.U. PER POUND COAL
1	MOWEAQUA LUMP	1-19-95	9.18	39.58	4375	743		11700
2	ODIN LUMP	1-23-95	6 20	40 25	46 02	753		11880
3	·· ··	2-23-95	6 32	3773	4445	11 50		
4	DU QUOIN LUMP	2-27-95	7.43	39.81	4510	766		
5	MT OLIVE	2· 95	799	3859	4451	891		
6	BLOOMINGTON LUMP	1·3-4-95	380	4390	43.50	880		11970
7	DU QUOIN LUMP	9-29-95	759	3577	4753	9.11		112 50
8	MOWEAQUA LUMP VEIN Nº1	12-13-95	8 77	3657	45.57	909		
9	·· " - - 2	12-13-95	708	42 80	4214	798		
10	" - - 5	12-13-95	8.00	39.53	46.00	6 47		
11	ODIN LUMP	2-10-96	9.10	36.46	4722	7 22		11430
12	DANVILLE SCREENINGS	5-25-96	940	33.30	3420	2310		9360
13	ODIN LUMP	4-9-95	710	3490	4809	991		11250
14	CARBONDALE & BIG MUDDY	5-8-96	6.08	39.78	4622	7.92		11070
15	" " " -	5-28-96	618	34.10	4912	1060		11430
16	PARADISE LUMP I.C. COAL & SALT Cº ST JOHNS	7-25-96	963	3700	5110	227		11970
17	MUDDY VALLEY LUMP ··	7-25-96	711	40.37	4823	429		11880
18	ODIN PEA	6-11-96	5 09	3793	4230	1468		10980
19	DU QUOIN LUMP	6-15-96	9.14	3461	50.87	5.40		12060
20	ODIN PEA	10-6-96	728	4125	45.23	6.24		11700
21	·· LUMP	11-6-96	724	4076	45.77	6.23		12240
22	" "	11-14-96	792	38.39	4557	8.12		12240
23	" ··	11-27-96	811	3573	4462	1154		11520
24	· SLACK	12-9-96	8 00	3431	42 26	15 43		111 60
25	FAIRMOUNT SCREENINGS	12-10-96	10 67	36.46	39.85	13 02		10890
26	ODIN LUMP	1-26-97	3 50	3830	47.35	1085		12330
27	·· PEA	1-31-97	420	3622	44.23	15.35		11790
28	·· LUMP	2-4-97	8 42	3403	41.85	1570		11790
29	·· "	2-9-97	8 55	36.10	44.15	1120		11520
30	SANGAMON LUMP	2-20-97	12.47	3544	4054	11.52		10980
31	PARADISE ··	2-26-97	10.72	3456	48.33	638		11700
32	ATHENS ··	3-25-97	12.11	3518	4195	1076		121.50
33	ODIN PEA	3-29-97	771	3543	42 44	1442		11520
34	BIG MUDDY WASHED SCREENINGS Nº 2	3-25-98	5 76	3025	57.32	6 67	1.18	12420
35	LAKE CREEK WASHED SCREENINGS	··	735	34.20	52.35	6.11	1.05	-
36	LAKE CREEK	··	3.42	39.30	53.04	408	172	12240
37	ODIN PEA	··	7.25	38 17	43 15	1135	3.61	10890
38	PANA SLACK	··	8.55	35 45	39.35	16 60	477	9810
39	GAS Cº PENNSYLVANIA	··	0.92	36 66	5894	346	1.40	12915
40	" " " COKE	··	2 80	450	7812	14.65	1.02	-
41	DU QUOIN SLACK	5-11-98	6 05	3595	4160	1640	514	11050
42	" "	1-12-95	7.02	3503	4460	13.39	-	10989
43	NIANTIC NUT	1-16-95	441	3425	4055	2079	-	10706
44	ODIN	3-6-95	632	3773	4445	11 50	-	10946
45	" PEA	· · 97	6 48	3195	3954	22.03	-	-
	Nºs 46-58 ASH ANALYSIS							
46	DU QUOIN ASH	1-12-95	.29	7.48	3436	67.87		
47	NIANTIC NUT "	1-16-95	.70	779	2340	6793		
48	MOWEAQUA "	1-19-95	.69	767	14.71	67.93		
49	ODIN ··	1-23-95	1.22	13 47	19.83	65.48		
50	" "	1-26-95	89	14 38	9.10	7563		
51	MT OLIVE "	2-23-95	53	329	19.06	77.12		
52	DU QUOIN NUT "	2-27-95	36	3 16	16.39	8009		
53	·· ·· ·· ··	2-27-95	33	6.03	11.24	8240		
54	ODIN "	3-6-95	.55	10.20	1630	72 95		
55	" "	3-6-95	10	5 28	8 66	85.96		
56	·· PEA "	–	17	432	8 03	8748		
57	" ·· ··	–	.14	4 73	7.89	87.24		
58	·· ·· ··	–	.20	391	817	8772		
59	GALESBURG	6-20-98	9.31	3605	3464	200	330	
60	ELMWOOD	6-20-98	938	4445	40 76	5 41	2.61	

ANALYSIS OF ILLINOIS COALS,
Compiled by the
Department of Applied Chemistry, University of Illinois.

WESTERN SOCIETY OF ENGINEERS.
Vol. VI. No. 3.—PLATE 6.
Breckenridge—Boiler Tests with Illinois Coals.

Nº	KIND OF COAL	DATE OF ANALYSIS	MOISTURE	VOLATILE COMBUSTIBLE	FIXED CARBON	ASH	SULPHUR	CALORIMETER B T U PER POUND COAL	Nº	KIND OF COAL	DATE OF ANALYSIS	MOISTURE	VOLATILE COMBUSTIBLE	FIXED CARBON	ASH	SULPHUR	CALORIMETER B T U PER POUND COAL
1	BUREAU Cº LADD		849	3353	4412	1376	-	10790	35	MACOUPIN Cº GILLESPIE		1261	3058	4527	1154	-	9.739.
2	FULTON Cº BUCKHEART		614	2994	4627	1765	-	10258	36	.. MT OLIVE		10.38	3668	4610	684	-	-
3	.. BRYANT		242	3291	4264	2203	-	9940	37	MºDONOUGH Cº COLCHESTER		1160	2502	4476	1862	-	9848
4	.. CANTON		351	3699	46.69	1281	-	10945	38	.. SLACK		530	25.48	3815	31.10	120	-
5	.. CLAIRE		316	3294	4305	2085	-	9988	39	MºLEAN Cº BLOOMINGTON		7.90	3402	5312	496	-	-
6	.. CUBA		417	3638	4862	10.83	-	11370	40	MADISON Cº COLLINSVILLE		920	45.89	3157	1334	534	10143
7	.. DUMFERLINE		246	3291	4557	1906	-	10471	41	PERRY Cº DU QUOIN		886	23.54	6060	700	-	-
8	.. SLACK		964	28.86	3948	22.02	-	9401	42	.. ..		703	35.03	4460	13.34	-	10989
9	.. FARMINGTON		341	3388	4589	1682	-	10471	43	. NUT		743	3891	46.00	766	.	11128
10	.. ST DAVID		200	3460	4620	1720	-	10732	44	. JUPETER		1130	3031	4991	848	.91	10710
11	GRUNDY Cº MORRIS		710	3212	4974	1104	.	10684	45	.. ST JOHN		982	2835	4577	16.08	206	9765
12	.. MORRIS		645	3086	5000	987	332	-	46	.. ..		1360	24.46	4354	1540	183	9828
13	HENRY Cº BLAIR BLUFF		1260	2396	4854	9.90	-	-	47	PEORIA Cº EDWARDS		320	3548	47.77	13.55	-	10945
14	.. KEWANEE		1560	2760	4966	714	-	-	48	.. ..		1.90	3448	43.62	20.00	-	9940
15	JACKSON Cº BIG MUDDY		4.85	2864	5780	596	2.75	-	49	.. ELMWOOD		136	2769	35.41	35.54	.	8820
16	.. ..		739	2828	5387	1046	.98	11466	50	.. .		760	2760	5530	950	.	-
17	.. ..		612	3095	5374	919	1.22	11529	51	.. POTTSTOWN		4.58	35.52	4552	1438	.	10790
18	.. ..		635	3150	5525	6.90	202	12657	52	.. MAPLETON		505	2924	59.02	495	1.74	-
19	.. ..		5.85	3184	55.72	659	292	11781	53	. LANCASTER		465	2915	5980	470	170	-
20	.. CARBONDALE		632	2640	5938	740	.	-	54	ST CLAIR Cº HEITZ BLUFF		895	3781	4824	500	.	10332
21	. MT CARBON		637	3193	5913	181	.76	-	55	. JOHNSON		5.50	4041	4053	1383	-	-
22	LA SALLE Cº LA SALLE		822	3940	4395	843	-	-	56	.. OAKLAND		830	3440	4312	1418	.	10395
23	.. .		587	3016	4850	1160	387	-	57	. REINECKE		756	39.81	4249	1014	-	-
24	.. OGLESBY		1212	3084	4932	772	-	-	58	. VULCAN NUT		7.44	30.86	45.09	1661	.	9450
25	.. STREATOR		445	3919	4405	1231	-	11399	59	. BELLEVILLE		705	2995	50.40	950	310	-
26	.. ..		830	3763	4593	814	-	11476	60	SANGAMON Cº LOOSES		1071	37.62	4507	66.0	.	.
27	.. ..		840	3825	4710	625	.	11727	61	.. RIVERTON		1106	3794	4298	802	-	-
28	.. ..		687	2911	4970	1120	312	-	62	SCHUYLER Cº RUSHVILLE		6.00	3160	5290	650	300	-
29	..		12.01	3532	4878	389	238	-	63	SHELBY Cº WO		717	3700	4209	1374	-	10383
30	LOGAN Cº LINCOLN		1092	2760	4664	1484	.	-	64	VERMILLION Cº DANVILLE		640	3011	51.12	925	312	-
31	.. ..		845	3499	4450	1206	.	-	65	. ..		578	4370	4537	615	-	-
32	MACOUPIN Cº ELLSWORTH		926	4222	4217	635	2.62	-	66	.. GRAPE CREEK		974	2834	5132	1060	-	-
33	.. GIRARD		970	3439	4576	1015	-	9954	67	SANGAMON Cº BARCLAY		1008	2732	4478	1700	.	-
34	. GILLESPIE		377	3494	4955	1174		-	68	WILL Cº WILMINGTON		712	2877	4936	1125	340	-

ANALYSIS OF BOILER WATERS,

By the

Department of Applied Chemistry, University of Illinois.

Western Society of Engineers.
Vol. VI. No. 3.—Plate 7.
Breckenridge—Boiler Tests with Illinois Coals.

REFERENCE					SCALING INGREDIENTS										NON-SCALING INGREDIENTS					TOTALS		
										CORRODING INGREDIENTS												
Nº	DATE	LOCALITY	SOURCE	DEPTH OF WELL FT	SILICA SiO_2	IRON & AL. OXIDE Al_2O_3 Fe_2O_3	CALCIUM CARBONATE $CaCO_3$	CALCIUM SULPHATE $CaSO_4$	MAGNESIUM CARBONATE $MgCO_3$	IRON SULPHATE $Fe_2(SO_4)_3$	MAGNESIUM SULPHATE $MgSO_4$	MAGNESIUM CHLORIDE $MgCl_2$	CALCIUM CHLORIDE $CaCl_2$	SODIUM NITRATE $Na(NO_3)$	SODIUM SULPHATE Na_2SO_4	SODIUM CHLORIDE $NaCl$	SODIUM CARBONATE Na_2CO_3	TOTAL ALKALIES	ORGANIC SUBSTANCES	TOTAL SCALING INGREDIENTS	TOTAL NON-SCALING INGREDIENTS	TOTAL SOLIDS
1	5-11-95	COAHOMA.	I.C.R.R.		0.64	0.120	6.18	TRACE	315	-	557	-	-	-	-	-	-	313	-	1566	313	18.79
2	6-22-95	NEW ORLEANS LA	McEWAN & MURRAY		035	0.110	0.25	-	0.45	-	-	-	-	-	-	-	-	2776	1.00	116	28.76	29.92
3	6-22-95	WINONA. MISS.	TANK I.C.R.R.		1.325	2346	2.001	-	-	-	-	-	-	-	-	-	-	-	1.80	5672	180	7.472
4	6-22-95	DUCK HILL. MISS	" "		1040	0.467	0.116	-	-	-	0502	-	-	-	-	-	-	0.508	2585	2.125	3.093	9.218
5	6-22-95	WEST. MISS DIV.	" "		1366	0.928	0233	0875	-	-	-	-	-	-	-	-	-	1850	2.277	3.402	4127	7929
6	6-22-95	DURANT. MISS.	" "		1.027	0794	2983	2460	0670	-	-	-	-	-	-	-	-	5230	0992	7.934	6222	14156
7	6-22-95	GRENADA. MISS.	" "		1091	-	-	7332	0648	-	-	-	-	-	-	-	-	6.380	1.240	9071	7.620	16.691
8	6-22-95	St JOHNS, MISS	" "		0.362	2333	-	36131	-	-	16256	-	-	-	-	-	-	19.363	3629	55142	22.992	78.134
9	6-22-95	CANTON. MISS DIV.	" "		1.710	0.263	6039	0.665	-	-	-	-	-	-	-	-	-	10.938	-	8.677	10.938	19.615
10	6-22-95	WAGS BLUFF	" "		0.566	0.508	0.408	0416	-	-	-	-	-	-	-	-	-	2976	0.584	1.898	3560	5.458
11	8-1-95	BURNSIDE, ILL.	POWER HOUSE "	400	0385	0.222	3058	2.183	-	-	0863	-	-	-	-	1285	4598	-	-	6711	5883	12.594
12	8-1-95	BURNSIDE, ILL	WELL UNDER TANK "	400	0.455	1.669	4332	-	1.403	-	0391	-	-	-	-	1.418	3.800	-	-	8.250	5218	13468
13	2-6-96	SOUTH PORT, LA	RIVER "		0.390	0.244	2.660	4.080	2126	-	0798	-	-	-	-	-	-	4488	-	10.298	4488	14.786
14	2-6-96	ELMHURST SPRINGS	" "		0.782	0.181	9631	8.522	7296	-	0.327	-	-	-	-	-	-	1.692	-	26.739	1.692	28431
15	2-10-96	MINONK, ILL.	COAL Co RESERVOIR		0.128	-	24920	15.760	10.900	-	4938	-	-	-	-	-	-	5061	-	56646	5061	61.707
16	3-6-96	WINONA, ILL.	CITY WELL	900	-	-	408	-	471	-	1280	-	-	-	14242	52.117	-	-	-	10070	66359	76.429
17	3-6-96	MINONK, ILL	CLAY PIT		177	-	2236	3882	036	-	27590	-	-	-	-	-	-	9448	-	91.500	94480	185.980
18	8-1-96	FORRESTON, ILL.	CITY WELL		1.021	2.882	15810	-	5394	-	087	-	-	-	-	-	-	2358	-	25.977	2358	78.335
19	8-1-96	FORRESTON, ILL.	" "		0.8106	0.1108	22.3948	1.1314	0.9447	-	2.2336	.1574	-	.1808	-	5.9309	3500	-	-	283833	62809	346647
20	8-1-96	MONTICELLO, ILL.	CITY WATER		0.875	0741	7476	-	4559	-	0460	-	-	-	-	-	-	8722	-	14111	8722	22.833
21	12-31-96	WINONA, ILL.	" "		07056	0.5074	91737	-	31994	-	-	-	-	-	04690	62.1170	12160	-	-	135861	63.8020	77388
22	2-5-97	FORRESTON, ILL.	TRIAL WELL I.C.R.R.		0810	0.110	22.995	1.131	0.944	-	2.233	01570	-	.180	-	5.930	0.350	-	-	28.380	6.460	34.84
23	2-23-97	ELMHURST, ILL.			0470	-	1409	5.95	2380	-	-	-	-	-	1.020	0380	2300	370	-	22.890	370	26.59
24	6- -97	St JOHNS, ILL.	I.C.C. & S Co	900	9.328	-	222.3562	719422	-	-	-	5505852	1195150	-	-	5930.776	-	5930.276	-	973.726	5930.276	6904.002
25	7-30-97	St JOHNS. ILL.	I.C.C. & S Co	900	1749	-	4081	79696	-	-	-	372653	536.823	NaBr 1.347	-	5366.515	-	5367862	-	1015.002	5367.862	6382.860
26	7-27-97	PANA, ILL.	CITY WATER		1749	-	11.513	-	3848	-	-	0670	-	-	5338	-	1241	-	-	17780	7.309	25.089
27	7-27-97	CACHE RIVER	I.C.R.R.		0.728	0.233	2.390	-	0685	-	-	-	-	-	-	-	-	2157	1.865	4.036	4022	8.058
28	7-30-97	LA SALLE, ILL.	SPRING "		0927	-	15304	5.999	-	-	0752	2.367	-	-	6.937	-	-	-	-	231449	6,937	38386
29	12-23-97	PANA, ILL.	TANK "		1.201	1.953	131513	-	2.4136	-	2.0113	03731	-	-	-	-	2.2445	-	-	21.8033	4.6289	26.4332
30	2-14-98	PANA. ILL.	" "		0.540	0080	821	-	3.31	-	-	0930	-	-	2050	-	2.620	-	-	13,130	4.670	17 80
31	2-18-98	GILMAN, ILL.	" "		1680	-	1409	11.02	4.23	-	17.05	-	-	-	4060	2430	-	-	-	48.070	6.49	54.56
32	8-13-98	St JOHNS ILL.	I.C.C. & S. Co	900	-	-	-	7598	.-	-	-	369732	60386	NaI .082	-	5166425	-	516724	-	1049.572	5167.24	6216.812
33		LAKE MICH.	TANK I.C.R.R.		0.46	0.39	6.44	-	1.72	-	-	-	-	-	1.47	0.05	0.85	-	-	9.01	2.37	11.38

ANALYSIS OF BOILER WATERS,
By the
Department of Applied Chemistry, University of Illinois.

WESTERN SOCIETY OF ENGINEERS.
Vol. VI. No. 3.—PLATE 8.
Breckenridge—Boiler Tests with Illinois Coals.

REFERENCE					SCALING INGREDIENTS										NON-SCALING INGREDIENTS					TOTALS			REMARKS
										CORRODING INGREDIENTS													
Nº	DATE	LOCALITY	SOURCE	DEPTH OF WELL FT	SILICA SiO_2	IRON & AL. OXIDE Al_2O_3 Fe_2O_3	CALCIUM CARBONATE $CaCO_3$	CALCIUM SULPHATE $CaSO_4$	MAGNESIUM CARBONATE $MgCO_3$	IRON SULPHATE $Fe_2(SO_4)_3$	MAGNESIUM SULPHATE $MgSO_4$	MAGNESIUM CHLORIDE $MgCl_2$	CALCIUM CHLORIDE $CaCl_2$	SODIUM NITRATE $NaNO_3$	SODIUM SULPHATE Na_2SO_4	SODIUM CHLORIDE $NaCl$	SODIUM CARBONATE Na_2CO_3	TOTAL ALKALIES	ORGANIC SUBSTANCES	TOTAL SCALING INGREDIENTS	TOTAL NON SCALING INGREDIENTS	TOTAL SOLIDS	
34		ELMHURST ILL	SPRING		048	-	1400	594	240	-	-	-	-	-	102	038	229	369		22 88	369	2657	
35		CLINTON ILL	BOILER SODA USED		-	-	-	-	-	-	.382	-	-	0.14	0.46	5759	138	5957		382	5957	6339	
36		CLINTON TO LA SALLE	" "		-	-	1.38	3619	-	-	-	848	29.04	835	-	10087	-	10922		7509	10922	18431	
37		CLINTON TO CENTRALIA	" NO SODA USED		-	-	072	60.44	-	-	-	1945	7998	1310	-	10312	-	11622		16059	11622	27681	
38		SUBURBAN	" ICRR		-	-	2 40	2721	-	-	061	-	-	-	597	2355	-	2952		3022	2952	5972	
39		RANTOUL ILL	" NO SODA USED		-	-	-	1232	-	-	-	-	-	597	2166	026	171	2960		1232	2960	4192	
40		PEORIA-MOREFIELD	" "		003	-	-	-	208	-	108	0.61	-	447	447	2.04	088	1186		385	1186	1571	
41		MOUNDS ILL	ICRR	40'	141	-	1428	-	135	0375	220	179	-	-	576	-	-	576		2140	576	2716	
42		MOUNDS ILL	HEATER		-	-	1081	477	6.49	-	372	-	-	-	-	212	-	212		2579	212	2791	
43		CHAMPAIGN ILL	DRIVE WELL ICRR	165	107	0.25	1171	265	2.62	-	-	-	-	-	-	013	495	508		1830	508	2338	
44		CHAMPAIGN ILL	BOILER		069	-	-	-	-	-	-	-	-	-	229	077	2707	30.13		0.69	3013	3082	
45		GILMAN ILL	TANK ICRR		069	011	365	1481	2 52	-	13.98	-	-	-	135	133	TRACE	268		35.76	2.68	3844	
46		GILMAN ILL	BOILER		-	-	331	2917	-	-	119	-	-	386	6362	17.05	-	8453		3367	84.53	11820	
47		MATTOON ILL	E L Cº		031	-	12.69	27.21	0.14	-	482	-	-	870	-	1306	-	21.76		4617	21.76	6693	
48		MATTOON ILL	BOILER		185	-	-	3016	-	-	2552	3.24	-	2088	-	24906	-	26' 94		60.77	26994	33071	
49		BURNSIDE ILL		400	081	0.25	403	-	153	-	-	-	-	-	092	185	243	520		662	520	1182	
50		BURNSIDE AND LAKE MICHIGAN	BOILER		-	329	742	-	-	-	062	-	-	-	2627	1425	-	4052		1133	4052	51.85	
51		SANGAMON	"		-	-	3480	4228	-	-	55.55	-	-	545	21761	5549	-	278.55		13263	27855	41118	
52		SANGAMON COAL Cº			-	-	32084	782502	32939	-	230860	-	-	-	325897	170236	-	-		1078393	496133	157.4526	
53		TOLONO ILL	CITY WELL	165	142	017	874	-	633	-	-	-	-	028	-	038	483	540		1666	5.49	2215	
54		TOLONO ILL	BOILER		-	-	-	-	-	-	-	-	-	001	-	284	8752	90.97		-	9097	9097	
55		BLOOMINGTON ILL	TANK C&A RR	80	074	-	2002	2998	0443	-	9797	-	-	-	2 00	097	-	297		33.998	2.97	3697	
56		CARBONDALE ILL	E L Cº		0.87	011	971	0.63	360	-	-	-	-	-	189	3531	1126	-		1492	6206	7698	
57	6 24·98	CARBONDALE ILL	WELL ICRR		8337	2273	2.3203	-	9211	-	-	-	-	-	64013	129426	218600	157687		43.024	157.6873	1619897	
58																							
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CXXII.

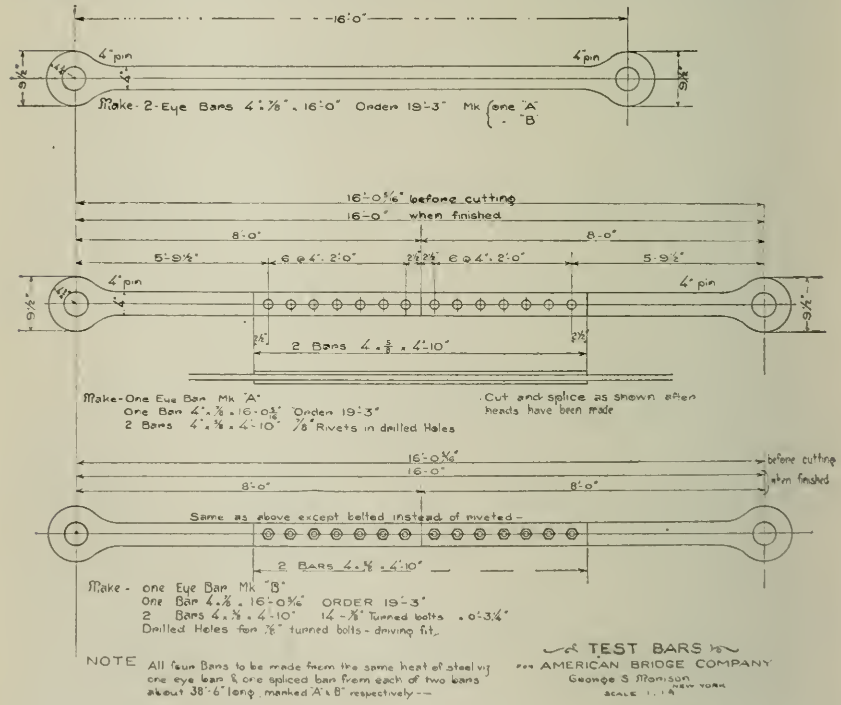
EFFECTS OF SPLICING AND RIVETING.

By George S. Morison, M. W. S. E.

Presented June 5, 1901.

The three features which govern the use of steel or iron as structural materials are: The modulus of elasticity (for which it is better to substitute a coefficient of elongation), the elastic limit, and the ultimate strength. Of these, the first determines the behavior of the metal under proper working strains. The two latter determine the limit, which must be put on such working strains, which may generally be taken at from one-third to two-thirds of the elastic limit, and from one-sixth to one-third of the ultimate strength. In tension members the passing of the elastic limit, or, more properly, of the yield point, represents such a distortion of the structure of which these members form a part as to be virtually its destruction. In compression members, a passing of the elastic limit usually means a distortion, which introduces rapidly accelerating tensile strains which soon destroy the member; the ultimate strength, which is not rupture, but absolute crippling, being little above the observed elastic limit. There is evidence that repeated tensile strains below the elastic limit will gradually weaken the material; there is no evidence that compression, which tends to compact instead of loosen, has any similar effect. The yield point is generally higher in compression than in tension members, and structures would be more correctly proportioned if based on the yield point for both classes of strains. Furthermore, in the judgment of the writer, in short compression members, a less factor of safety can be used than in tension members. This means larger unit stresses in short compression members than in tension members. The writer believes that many important structures are loaded with unnecessary metal in compression members, and that stronger structures could be built with the same amount of metal if a portion were taken from the compression and placed in the tension members.

In compression members the ultimate crippling is determined by other than compressive strains; the actual stress in a member after it passes the elastic limit being of a complicated character. In a solid, unspliced tension member the strains are of the simplest character conceivable. As soon as splices and irregularities are introduced this simplicity disappears, and complications, whose effects can only be determined by experiment, are introduced. Any such features qualify the ability of the member to change its shape; the coefficient of elongation, the yield point, and the ultimate strength are dependent upon this ability to change shape. The primer of testing recognizes the need of a sufficiently long minimum section to allow the test specimen to draw down at point of fracture, a short minimum section giving much higher results than a long one, the difference increasing with the ductility of the metal. On this principle, a hole bored in a bar, while reducing its cross section reduces its ultimate aggregate strength to some degree, but materially less than the reduction of the section; the opportunity for the bar to draw down at the point of fracture is reduced, but stretching would occur and be accompanied by an elongation of the hole; if the hole is filled with a rivet, resistance to the elongation of the hole is introduced and this would have some further effect. In the writer's practice a case occurred in


16'0"
4" pin
4" pin
9½"
9½"
4"
Make - 2 - Eye Bars 4" × ⅞" × 16'-0" Order 19'-3" Mk { one "A" / " "B"
16'-0 5/16" before cutting
16'-0" when finished
8'-0"
8'-0"
5'-9½"
6 @ 4". 2'-0"
2½ 2½
6 @ 4". 2'-0"
5'-9½"
4" pin
4" pin
9½"
9½"
4"
2½"
2½"
2 Bars 4 × ⅝ × 4'-10"
Make - One Eye Bar Mk "A"
One Bar 4" × ⅞ × 16'-0 5/16" Order 19'-3"
2 Bars 4" × ⅝ × 4'-10" ⅞" Rivets in drilled Holes
Cut and splice as shown after heads have been made
16'-0 5/16"
before cutting
16'-0"
when finished
8'-0"
8'-0"
Same as above except bolted instead of riveted -
2 Bars 4 × ⅝ × 4'-10"
Make - one Eye Bar Mk "B"
One Bar 4 × ⅞ × 16'-0 5/16" ORDER 19'-3"
2 Bars 4 × ⅝ × 4'-10" 14 - ⅞" Turned bolts × 0'-3¼"
Drilled Holes for ⅞" turned bolts - driving fit
NOTE All four Bars to be made from the same heat of steel viz one eye bar & one spliced bar from each of two bars about 38'-6" long, marked "A" & "B" respectively --
TEST BARS
for AMERICAN BRIDGE COMPANY
George S Morison
NEW YORK
SCALE 1:1/4

which it seemed expedient to splice an adjustable tension member by riveting or bolting splice bars on each side. Fortunately the structure had been so proportioned that the unit stress on this member was very low; but before advising this method of splicing, it seemed best to make some actual tests on bars spliced in substantially the manner proposed.

Four bars of soft steel were constructed by the American Bridge Company at its Pencoyd works, two of which were solid bars and two of which were cut in the center and spliced. The details of these bars are shown on the plan which accompanies this paper. In both of the spliced bars the holes were reamed. In one of them the splices were riveted on, and in the other they were fastened with close fitting turned bolts. The bars were all made of the same steel,the manufacturer's report of which is given in Appendix A.

These four bars were all broken in the Government testing machine at the U. S. arsenal at Watertown, Mass., in January, 1901, and a copy of the official report is attached to this paper and is marked Appendix B.

The elongations of the several bars under strain in the machine have been plotted, and the curves showing these elongations under strain are given on the blue print attached to this paper and marked Appendix C.

The solid bars broke in the body of the bar under strains averaging 56,915 pounds per square inch, one of them showing a total elongation of 14.7 per cent and a reduction of area at fracture of 53.5 per cent, and the other a total elongation of 18 per cent and a reduction of area at fracture of 54.7 per cent. Each of the spliced bars broke in the rivet or bolt hole nearest to one of the heads, and showed comparatively small elongation but a large reduction at point of fracture, the elongations being respectively 3.6 and 3.7 per cent, and the reductions 45.6 and 43.5 per cent. The metal showed signs of over straining and had begun to draw down opposite the rivet or bolt at the other end of the splice. All this was to be expected, as the full strain was taken here on the section of the bar reduced by the hole. The net section of the riveted bar at the rivet holes, which were 0.94 inch in diameter, was 76.5 per cent of the full section of the bar. The net section of the bolted bar at the bolt holes, which were 0.87 inches in diameter, was 78.25 per cent of the full section of the bar.

The mean ultimate strength of the spliced bars was 46,870 pounds measured on the original section of the unspliced bar, or 82 per cent of the mean ultimate strength of the solid bars. The mean elastic limit of the unspliced bars, according to the official reports, was 28,500 pounds, and that of the only spliced bar reported (the riveted bar) was 25,000 pounds, or 88 per cent of that of the solid bars. A study of the elongations as plotted would seem to indicate that the yield point of the solid bars was practically 30,000 pounds and of the spliced bars 26,000 pounds, or 87 per cent that of the solid. All unit stresses are referred to the original section of the bar without allowance for reduction by holes or increase by metal in splices. But the average section of the spliced bars at the hole where the fracture occurred was 23 per cent less than that of the solid bar, so that the actual stress per square inch where the fracture occurred was 6.4 per cent more in the spliced bar than in the solid bar. The yield point was about 12 per cent greater. This result is in accordance with those obtained in testing short specimens of ductile metal as compared with specimens of sufficient length to allow full contraction to occur. On the other hand, the form of these test bars allowed a considerable contraction to occur at the rivet or bolt hole where they broke. These results are summarized in the following table:

		STRESSES PER SQUARE INCH			PER CENT.	
Number.	Bar.	Ultimate.	Elastic Limit.	Yield Point by Diagram.	Elongation	Reduction.
11,397	Solid	57,730	28,000		14.7	53.5
11,400	"	56,100	29,000		18	54.7
Q	Average Solid	56,915	28,500	30,000	16.6	54.1
11,398	Riveted	45,640	25,000		3.6	45.6
11,399	Bolted	48,100			3.7	43.5
R	Average Spliced	46,870	25,000	26,000	3.6	44.5
11,398	Net Section	59,662	32,680			
11,399	Net Section	61,472				
S	Average Net Section	60,567		33,592		
	$\frac{R}{Q}$	82.2	87.7	86.7		
	$\frac{S}{Q}$	106.4		112		

This table shows that the ultimate strength of the spliced bars was about 18 per cent and the elastic limit about 12 per cent less than that of the solid bars.

A study of the plotted elongations shows that below a stress of 26,000 pounds per square inch, the elongations of the riveted bar were a little less than that of the solid bars, this difference evidently being due to the relief in the center of the bar given by the increased section of the splices. On the other hand, the bolted bar shows a slightly greater elongation than the solid bars, this difference probably being due to the fact that the bolts, though tight, were not an absolute fit, and a slight movement took place around them. The bolts admitted of two motions on each side of the splice. The total difference of elongation between the riveted bar and the bolted bar under 20,000 pounds stress was 0.06 inch. This would have been explained by a play in the bolt holes of 0.15 inch.

A study of the plotted curves shows some instructive general results. Up to a 26,000 stress the action of all the bars was practically the same, and if we exclude the bolted bar, the action may be said to be identical. After passing the yield point the action of the bars was practically the same until an elongation of two inches, or 1.25 per cent of the gauged length, was reached. Above this the elongation of the spliced bars was considerably less than that of the solid bars, the difference being due to the larger section of the spliced portion of the bar.

In spite of the reductions in the elastic limit and ultimate strength, the action of the spliced bars was identical with the unspliced bars under all stresses which would be considered within permissible working limits on an actual structure.

On the basis of behavior under working stresses we should be justified in working the spliced bar up to the gross strain that we should put on a solid bar. On the basis of elastic limit we should be justified in working the spliced bar up to seven-eighths the gross strain we should put on a solid bar. On the basis of ultimate strength we should be justified in working the spliced bar up to nearly five-sixths the gross strain we should put on a solid bar. On the basis of net sections, after deducting for rivet or bolt holes, we should be justified in working the spliced bar up to a unit stress from six to eleven per cent greater than we should put on a solid bar.

A further general conclusion to be drawn is that in proportioning solid beams, like plate girders, it is more correct to use the gross section than the net section. Care should be taken so to arrange the rivet holes as to cut away the material as little as possible, and the limiting strain should be determined after a fair consideration of how much the actual section is reduced; but if the actual net section is reduced 10 per cent by rivet holes, it is perfectly safe to reduce the permissible gross section strain only 5 per cent. The writer believes the only proper way to proportion plate girders is to treat them as solid beams, and to determine the strain in extreme fibers by using the moment of inertia of the entire beam including the web. Not only is this practice theoretically correct, but it has the decided practical advantage of discouraging the use of thin metal in the webs, thereby producing a girder which is not only well adapted to use, but which will suffer least injury from abuse. Assuming 10,000 pounds as the strain which would be put on the extreme fibers of such girder if it were a solid rolled beam, it would in almost every instance be possible to design a built beam in which the strain on extrēme fibers should be allowed to reach 9,500 pounds per square inch as calculated on the gross section.

APPENDIX A.

PENCOYD IRON WORKS.

Record of Chemical and Physical Tests of Steel Flats.
Rolled for D 369.

PENCOYD, OCT. 12, 1900.

TEST No.	HEAT.	SIZE.
	10.4464	4-in. flat.

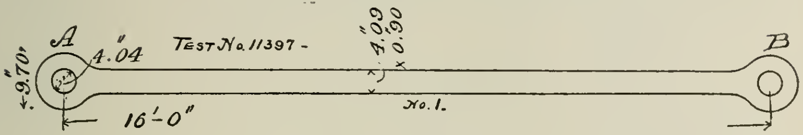
Original dimensions, 1.800 × .670   Original area, 1.566
Elastic limit, 60,100 pounds.   Per sq. in., 38,380 pounds.
Ultimate strength, 93,000 pounds.   Per sq. in., 59,380 pounds.
Elongation in 8 inches, 2.40 in.=30.00 per cent.
Reduced dimensions, 1.500 .500   Reduction, 52.1 per cent.
Reduced area, .750
Fracture, silky cup.
C., 0.20 per cent. Sul., 0.04 per cent. Phos., 0.02 per cent. Mn., 0.45 per cent.

Remarks: Bend, 180° flat.

(Signed) A. J. CHRISTIE,
Inspecting Engineer.

REPORT OF MECHANICAL TESTS

Made with U. S. Testing Machine, Capacity 800,000 pounds, at Watertown Arsenal, January 4, 1901.

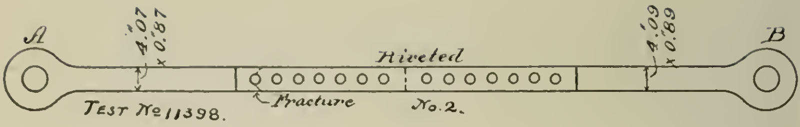


Sectional area, 3.681 sq. in.
Gauged length, 160 in.

APPLIED LOADS.		IN GAUGED LENGTH.		REMARKS.
Total, pounds.	Pounds per square inch.	Elongation, inches.	Set, inches.	
3,681	1,000	0.	0.	Initial load
18,405	5,000	.0244	.0005	
36,810	10,000	.0529	.0008	
55,215	15,000	.0812	.0013	
58,896	16,000	.0867		
62,577	17,000	.0922		
66,258	18,000	.0978		
69,939	19,000	.1022		
73,620	20,000	.1090	.0017	
77,301	21,000	.1145		
80,982	22,000	.1203		
84,663	23,000	.1257		
88,344	24,000	.1316		
92,025	25,000	.1375	.0035	
95,706	26,000	.1435		
99,387	27,000	.1498		
103,068	28,000	.1562		Elastic limit.
106,749	29,000	.1653		
110,430	30,000	.1830	.0220	
114,111	31,000	.2222		
117,792	32,000	.7800		
		.8220	.6461	Elongation 2 min. later than first observation.
121,473	33,000	1 03		
125,154	34,000	2.10		
128,835	35,000	2.97		
132,516	36,000	3.22		
136,197	37,000	3.44		
139,878	38,000	3.72		
143,559	39,000	3.98		
147,240	40,000	4.35		
150,921	41,000	4.67		
212,500	57,730			Tensile strength.
0	0	23.69=		14.7%

Area at fracture 3.00 in. × 0.57 in. = 1.71 sq. in.	Contraction 53.5%.
Elongation of 10-in. sections:	1.26 1.60 1.88 1.50 1.37 1.34 1.36 1.34 1.32 1.39 2,82* 1.93 1.21 1.10 1.07 1.10
Elongation of pin holes:	A .52in., B .96 in.

Appearance, silky.
*Indicates fractured section.



Sectional area, 3,622 sq. in.
Gauged length, 160 in.

APPLIED LOADS.		IN GAUGED LENGTH.		REMARKS.
Total, pounds.	Pounds per square inch.	Elongation, inches.	Set, inches.	
3,622	1,000	0.	0.	Initial load.
18,110	5,000	.0164	.0020	
18,110	5,000	.0163	.0024	Observation repeated.
21,732	6,000	.0207		
25,354	7,000	.0254		
28,976	8,000	.0300		
32,598	9,000	.0349		
36,220	10,000	.0394	.0036	
39,842	11,000	.0446		
43,464	12,000	.0494		
47,086	13,000	.0543		
50,708	14,000	.0591		
54,330	15,000	.0637	.0056	
57,952	16,000	.0689		
61,574	17,000	.0739		
65,196	18,000	.0788		
68,818	19,000	.0842		
72,440	20,000	.0890	.0079	
76,062	21,000	.0945		
79,684	22,000	.0998		
83,306	23,000	.1047		
86,928	24,000	.1104		
90,550	25,000	.1164	.0129	Elastic limit.
94,172	26,000	.1255		
97,794	27,000	.1600		
101,416	28,000	.1940		
105,038	29,000	.2185		
108,660	30,000	.3250	.2038	
108,660	30,000	.3895	.2529	Observation repeated.
112,282	31,000	.6300		Scaling opposite end rivets and generally along the bars.
115,904	32,000	1.30		
119,526	33,000	2.06		
123,148	34,000	2.22		
126,770	35,000	2.40		
130,392	36,000	2.59		
134,014	37,000	2.84		
137,636	38,000	3.07		
141,258	39,000	3.36		
144,880	40,000	3.63		
148,502	41,000	3.97		

Elongation of 10-in. sections, under load of 41,000 lbs. per sq. in., beginning at end A:

.37 .35 .35 .34 .37 .30 .03 .00 .08 .03 .30 .35 .36 .36 .35 .34

APPLIED LOADS.		IN GAUGED LENGTH.		REMARKS.
Total, pounds.	Pounds per square inch.	Elongation, inches.	Set, inches.	
Elongation of 10-in. sections, bar under load 1,000 lbs. per sq. in., .35 .34 .33 .32 .35 .29 .02 .02 .08 .02 .29 .34 .34 .34, .34 .32.				
165,300	45,640			Tensile strength.
0	0	5.81 in.		3.6%

Area at fracture, 2.70×.73=1.97 sq. in. — Contraction 45.6%.

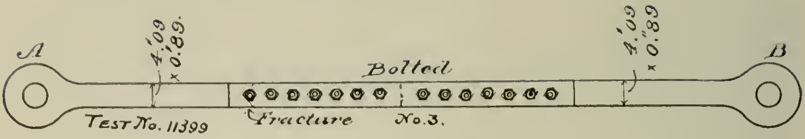
Elongation of 10-in. sections: .46 .43 .43 .43 .46 .86* .02 .01 .11 .02 .44 .44 .45 .45 .44 .42

Elongation of pin holes: A .41 in., B .22 in.

Appearance, silky.

Fractured at end A, across the first rivet hole.

Width of bar end B, opposite end rivet, 3.88 in.

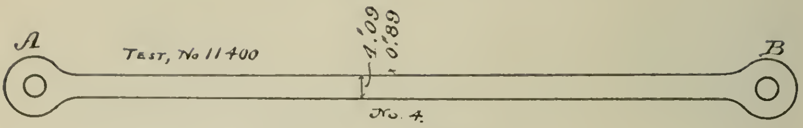


Sectional area, 3.64 sq. in.
Gauged length, 160 in.

APPLIED LOADS.		IN GAUGED LENGTH.		REMARKS.
Total, pounds.	Pounds per square inch.	Elongation, inches.	Set, inches.	
3,640	1,000	0.	0.	Initial Load.
7,280	2,000	.0129		
10,920	3,000	.0224		
14,560	4,000	.0323		
18,200	5,000	.0402	.0121	
21,840	6,000	.0472		
25,480	7,000	.0537		
29,120	8,000	.0597		
32,760	9,000	.0658		
36,400	10,000	.0716	.0162	
40,040	11,000	.0770		
43,680	12,000	.0833		
47,320	13,000	.0889		
50,960	14,000	.0959		
54,600	15,000	.1055	.0255	
58,240	16,000	.1178		
61,880	17,000	.1265		
65,520	18,000	.1338		
69,160	19,000	.1409		
72,800	20,000	.1489	.0447	
76,440	21,000	.1569		
80,080	22,000	.1643		
83,720	23,000	.1716		
87,360	24,000	.1782		
91,000	25,000	.1862	.0562	
94,640	26,000	.1993		
98,280	27,000	.2280		
101,920	28,000	.2715		
———	———	———	———	Rested under load 20 minutes.
105,560	29,000	.2870		
109,200	30,000	.3133	.1558	
112,840	31,000	.3400		
116,480	32,000	.4430		
120,120	33,000	.7930		
123,760	34,000	1.70		
127,400	35,000	2.20		
131,040	36,000	2.38		
134,680	37,000	2.50		
138,320	38,000	2.72		
141,960	39,000	2.93		
145,600	40,000	3.21		
149,240	41,000	3.51	3.28	

APPLIED LOADS.		IN GAUGED LENGTH.		REMARKS.
Total, pounds.	Pounds per square inch.	Elongation, inches.	Set, inches.	
149,240	41,000			Load re-applied and elongation of 10-in. sections measured while under this stress: .31 .30 .30 .30 .30 .27 .02 .08 .00 .02 .29 .30 .30 .31 .29 .28
Load released to 1000 lbs. per sq. in. and 10-in. sections remeasured: .29 .28 .29 .28 .29 .25 .01 .06 .00 .02 .27 .28 .29 .30 .28 .27				
175,100	48,100			Tensile strength.
0	0	5.98 in.		3.7%
Area at fracture, 2.78×.74=2.057 sq. in.				Contraction 43.5%.
Elongation of 10-in. sections:				.46 .44 .45 .44 .46 .79* .03 .16 .01 .04 .47 .45 .46 .46 .44 .42
Elongation of pin holes: Appearance, silky. Fractured across first bolt hole, end A.				A .45 in. B .32 in.
Elongation of bolt holes:				.73* .10 .04 .02 .01 .02 .01 .02 .01 .01 .01 .02 .01 .05 .11 .28

The elastic limit of this bar is not well defined.



Sectional area, 3.64 sq. in.
Gauged length, 160 in.

APPLIED LOADS.		IN GAUGED LENGTHS.		REMARKS.
Total, pounds.	Pounds per square inch.	Elongation, inches.	Set, inches.	
3,640	1,000	0.	0.	Initial load.
18,200	5,000	.0229	.0004	
36,400	10,000	.0502	.0008	
54,600	15,000	.0775	.0011	
72,800	20,000	.1047	.0013	
76,440	21,000	.1100		
80,080	22,000	.1157		
83,720	23,000	.1214		
87,360	24,000	.1269		
91,000	25,000	.1324	.0021	
94,640	26,000	.1384		
98,280	27,000	.1449		
101,920	28,000	.1512		
105,560	29,000	.1585		Elastic limit.
109,200	30,000	.1765	.0196	
112,840	31,000	.3911		
116,480	32,000	.9400		
120,120	33,000	2.48		
123,760	34,000	3.10		
127,400	35,000	3.31		
131,040	36,000	3.55		
134,680	37,000	3.90		
138,320	38,000	4.15		
141,960	39,000	4.50		
145,600	40,000	4.84		
149,240	41,000	5.29	5.02	
149,240	41,000			Load re-applied and elongation of 10 in. sections measured while the bar was under stress.
				.34 .37 .36 .35. .36 .35 .35 .34 .35 .35 .34 .34 .31 .32 .33 .32

Load released to 1000 pounds per square inch and 10 sections remeasured.

.32 .35 .35 .34 .34 .33 .33 .33 .33 .33 .33 .32 .29 .30 .31 .30

204,200 56,100 Tensile Strength.

0 1 28.81 in. 18%

Area at fracture, 3.01×0.55=1.65 sq. in. Contraction, 54.7%

Elongation of 10-in. sections	1.62	3.48*	2.84	1.79
	1.63	1.61	1.62	1.65
	1.61	1.66	1.95	1.84
Appearance, silky.	1.41	1.37	1.31	1.42

Correct:
J. E. Howard

John G. Butler,
Maj. Ord. Dept. U. S. A., Commanding.

SUPPLEMENTARY OBSERVATIONS ON EYE-BARS
Nos. 11398 AND 11399.

The rivets in eye-bar No. 11398 next the joint measured 0.94 in. diameter, taken parallel to the axis of the bar, and 0.93 in. + at right angles thereto.

They are slightly distorted by the shearing stress encountered during the test, sufficient to show lines indicating the joints between the stem of the eye-bar and the covering plates.

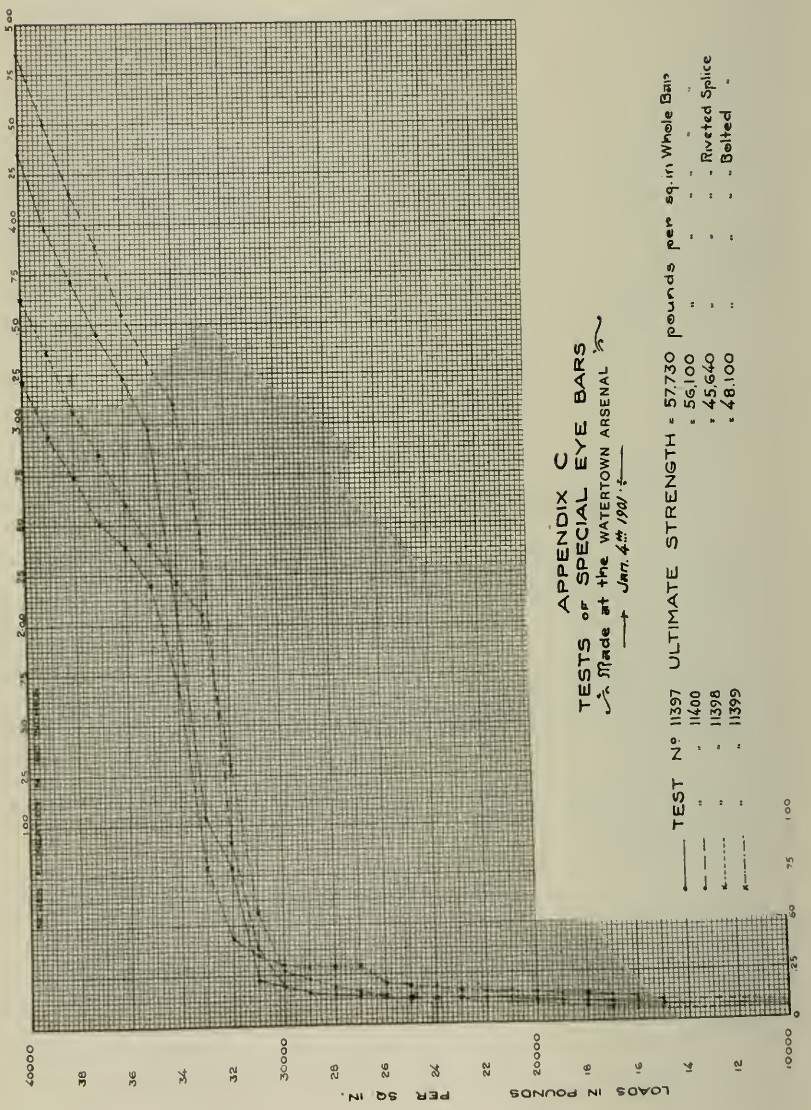
The outside rivet end B of the eye-bar, opposite the fracture, was partially sheared, and showed an offset of about .08 in This rivet hole measured 1.24 diameter, taken parallel to the axis of the eye-bar, thus showing an elongation of .31 in.

From bolted bar No. 11399 the bolt next the joint measured .87 in. diameter, and did not differ .01 in. taken lengthwise or crosswise the direction of the axis of the eye-bar.

The end bolt showed partial shearing of about the same extent as the end rivet in the preceding test, but retained the same diameter in each direction within the amount of .01 in.

Correct.
J. E. Howard.

John G. Butler,
Maj. Ord. Dept. U. S. A., Commanding.


APPENDIX C
TESTS OF SPECIAL EYE BARS
Made at the WATERTOWN ARSENAL
Jan. 4th 1901
TEST Nº 11397 ULTIMATE STRENGTH = 57,730 pounds per sq. in Whole Bar
" " 11400 " " = 56,100 " " " " " "
" " 11398 " " = 45,640 " " " " - Riveted Splice
" " 11399 " " = 48,100 " " " " - Bolted "
LOADS IN POUNDS PER SQ. IN.
40000
38
36
34
32
30000
28
26
24
22
20000
18
16
14
12
10000
0
.25
.50
75
100
25
50
75
1.00
25
50
75
2.00
25
50
75
3.00
25
50
75
4.00
25
50
75
5.00

DISCUSSION.

Prof. A. N. Talbot, M. W. S. E., University of Illinois—It is not an uncommon belief that the drilling of a hole in a bar does not reduce the strength of the bar in proportion to the reduction in net cross section, and it is also to be presumed that if the hole is filled with a rivet, the resistance to the elongation of the rivet hole by the rivet will further increase the strength in the net section. It seems fortunate that tests on a large scale to determine the amount of this gain should be made. The writer does not wish to question the conclusion reached in the paper, that "on the basis of behavior under working stresses we should be justified in working the spliced bar up to the gross strain that we should put on the solid bar. On the basis of elastic limit we should be justified in working the spliced bar up to nearly seven-eighths the gross strain we should put on a solid bar. On the basis of ultimate strength we should be justified in working the spliced bar up to five-sixths the gross strain we should put on a solid bar." However, as he understands the paper these deductions can not properly be considered established by the tests made, so far as they are reported in the paper.

It will doubtless be admitted that the stretching of soft steel bars beyond the elastic limit, the elongation of the rivet holes, the distortion of the rivets, and the changed distribution of the stresses among the rivets, give such different conditions that a comparison of the ultimate strength of the spliced bar with the ultimate strength of a solid bar is no criterion of the relative strength within the elastic limit, and hence that the relative ultimate strength cannot be taken as evidence for determining the proper working stress.

Within the elastic limit, to compare stresses recourse must be had to the amount of elongation, and this is the method taken by the author of the paper. It seems to the writer, however, that the data presented are insufficient to establish the conclusion quoted above. To determine the effect of the load upon the reduced section, the elongation for a length along the reduced section should receive especial measurement.

To show the line of argument taken by this discussion, the tests described may be likened to an investigation of two chains, one having, say, 160 links of the same size and strength, and the other of similar makeup, but having two of its links replaced with slightly smaller links, and several more replaced with larger and stiffer links. If the second chain does not stretch as much as the first, or if the point at which a marked set appears in the second is nearly as high as in the first, the conclusion that the chain with the unequal links is nearly as strong, or even stronger, is hardly warranted. Let us see what is given in the tests.

The elongations were measured in a gauged length of 160 inches, and of this only 53 inches was occupied by the splice, and the lengths having sections reduced by the rivet hole, occupied less than one-third of this distance. Further, of the 13 inches of length having rivet holes, one-third (that near the sides of the holes) has lost little metal, and the total length having reduced sections is a very small part of the gauged length.

The distribution of the load among the several rivets, in transmitting the stress from the splice plate to the bars, is unknown; but assuming that on each side of the joint it is equally divided amoung seven (7) rivets, the reduced section of the bar at the end rivet would carry all the load, that at the second rivet six-sevenths of the load, and so on to that at the rivet next to the cut, which would carry one-seventh of the load. At most of the holes, then, the net section would carry a less unit stress than the full bar, while between rivet holes the unit stress is still less. Variations from this assumed distribution of load to the several rivets will give similar results.

It is to be expected, then, that the spliced bar will give a smaller unit deformation than the full bar, since much of the spliced portion is subject to a smaller unit stress. The test of the two bars confirms this, but it does not seem to touch the question of elongation at the end rivet holes, and therefore it does not test the unit stress there. If the weakest link governs the strength of the chain, the unit stress and deformations in the reduced section at the end rivets should be considered and not average values for the gauged length. No measurement of the deformations within the elastic limit at the end rivet holes is given. Nothing, then, seems to be established concerning the stress at the weak point of the bar, the end rivet holes.

A similar objection may be made to the process used to find what effect splicing has upon the elastic limit. Counting the effect of the two end holes to be equivalent to a reduced section along, say, 1 inch of length, and making a somewhat smaller allowance for the hole next to the end hole (since the unit stress on this will be less), the length of the reduced section under consideration would be less than 1-100 of the gauged length. As at the other holes there will be a smaller unit stress, we may consider only the portion above specified as likely to be stretched beyond the elastic limit. To show that it is possible that the elastic limit for the reduced sections at the rivet holes may have been reached before the elastic limit given in the tests, note that in the tests of the riveted bar the increase in elongation from 21,000 to 22,000 lbs. per square inch is .0053 inch; from 22,000 to 23,000 lbs. per square inch .0049 inch; and from

23,000 to 24,000 lbs. per square inch .0057. The last amount varies from the average of the others by .0006 inch. As a decrease in the modulus of elasticity of 25 per cent for the reduced section under consideration for this short length of 2 inches or so would give an increase of elongation over that for a constant modulus of elasticity of only .0003 inch, the elastic limit of the reduced section may have been reached a 23,000 lbs. per square inch and even before. At any rate the limit of accuracy of the work done will not permit a close determination of the elastic limit of the reduced section. So far as the test is concerned, the general elastic limit of the entire bar has been sought and not the elastic limit of the weakest part of it.

As has been stated, a distribution of the load other than equally among the rivets would give quite similar results, and some distributions would give even more severe conditions. A single line of rivets as in a splice of this kind, of course, gives an undesirable distribution of stress among the rivets. With the riveted joints used in closed cylinders like boilers, this difficulty may in part be avoided by making a smaller number of rivets in the outer row than in the rows nearer the seam.

Little can be told concerning the bolted splice, since the play of the bolts, the adjustment of stresses and deformations, and variations in fit will greatly complicate the distribution of stresses and deformations.

The matter under discussion is of importance, and has an application not only to spliced joints of the kind tested, but also to riveted joints and to built sections like plate girders. It has been felt by many engineers for some time that judiciously placed holes, well riveted, do not weaken a piece in tension or compression as much as the use of the net section in the calculation would indicate, and investigations proving this will be of service to the engineering profession. The writer sees some of the difficulties in making tests which will be conclusive. It does seem, however, that extensometer readings on reduced sections carrying a known load will give valuable data. Possibly, too, observations within the elastic limit (1) upon an unspliced bar having a large number of holes drilled in it, (2) upon a bar similarily drilled, but having the holes filled with rivets (riveted, but with no splice plate), and (3) upon a solid bar, would throw light in a way not otherwise to be obtained. Of course these observations may all be made upon the same bar. The writer hopes to undertake an investigation of this kind as soon as the new Materials Testing Laboratory of the University of Illinois, which is to replace the one destroyed by fire, is completed.

Mr. J. A. L. Waddell, C. E., Kansas City, Mo. — The principal deductions made by Mr. Morison from his experiments, while interesting, are by no means new; as the same results were found and recorded twenty years ago by Prof. Alex. B. W. Kennedy, in proof of which statement I quote the following from p. 329 of Burr's "Elasticity and Resistance of the Materials of Engineering," published in 1883.

"The experiments of Prof. Alex. B. W. Kennedy, on the effect of punching and drilling holes in mild-steel boiler plate, are well illustrated by Table XXVII, which is condensed from one given in London "Engineering," May 6th, 1881. None of these plates were annealed, but all were drilled or punched as received. Within the limits of these experiments, Prof. Kennedy observes, neither the width of the test piece nor the different diameters of the die had any essential influence on the results.

"The injurious effect of punching is shown by the fact that the punched specimens gave only 92 to 98 per cent of the resistance of the drilled ones.

"It will be noticed that both the drilled and punched specimens gave higher resistances than the natural plate. This is due to the 'shortening' and other influence (i. e., the disturbance of the lateral strains) of the rivet holes, as before observed and explained in Art. 32, 'Ultimate Resistance and Elastic Limit.'

TABLE XXVII.

Punched and Drilled Holes.

Thickness in inches	Hole, inches	Diameter of hole, inches	Tenacity in tons, sq. in. net section	Tenacity compared with that of	
				Nat. Plate	Drl'd Pl.
¼	Drilled	0.940	38.12	1.105	....
¼	Drilled	0.940	38.22	1.108	....
¼	⅞ punch, $\frac{31}{32}$ die	0.912–0.876	35.04	1.000	0.918
¼	⅞ punch, $\frac{29}{32}$ die	0.892–0.871	34.44	1.025	0.902
⅜	Drilled	0.926	35.39	1.126	....
⅜	Drilled	0.934	34.90	1.111	....
⅜	⅞ punch, 1 die	0.998–0.890	33.91	1.073	0.965
⅜	⅞ punch, $\frac{15}{16}$ die	0.945–0.875	34.38	1.096	0.978

I cannot agree with Mr. Morison in all the conclusions that he draws from his experiments.

It does not seem logical to strain metal higher than usual simply because it has been abused and injured by brutal treatment in the shops. Again, who can tell whether this increase of strength is permanent, or whether it will diminish gradually in time?

If plate girder flanges were proportioned by the gross section alone, as recommended in the paper, it would lead to very careless designing in the location of rivet holes.

I agree with Mr. Morison that the proper way to proportion plate girders is to treat them as solid beams, and to determine the extreme fibre stress by using the moment of inertia of the entire beam, including the web. Such has been my practice for many years, as is shown by my specifications. However, I always deduct for rivet holes in both flanges and web, assuming that there is a pair of stiffeners at the point considered.

I agree also with Mr. Morison's statement, that "in short compression members a less factor of safety can be used than in tension members." In my specifications (De Pontibus, pp. 155 and 156), shape metal is strained in tension 16,000 lbs. per square inch on the net section, when the entire stress is reduced to that of an equivalent dead load, and to $18{,}000-70\frac{e}{r}$ in compression.

Mr. Modjeski—I fully agree with Morison in his belief that many important structures are loaded with unnecessary metal in compression members. This is especially liable to occur in members designed to sustain reversals of stresses, the usual practice being to add from 70 to 100 per cent of the smaller stress to the greater one, and to make the section of the member equal to this sum, divided by the unit strain corresponding to the greater one of the two stresses. As in long compression members the unit strains are generally smaller than in tension members, it results that the foregoing method makes a greater allowance for fatigue of metal in compression than in tension. Mr. Morison justly remarks that "there is evidence that repeated tensile strains below the elastic limit will gradually weaken the material; there is no evidence that compression which tends to compact instead of to loosen, has any similar effect." While it is doubtful to me that the repetition of stresses, in bridge members for instance, is of such character as to weaken the metal, yet if allowance be made for it, this allowance should be greater for tensile than for compressive stresses. I have been using the following rule for members with reversible stresses: Let us call T the total maximum tension, C the total maximum compression, s allowable unit strain for tension, s_1 allowable unit strain for crippling, s_2 allowable unit strain for short compression members, or crushing. s is taken generally at 10,000 lbs. per sq. inch, s_2 at 14,000 or 15,000, and s_1 varies with the length and radius of gyration of the member, and may be here assumed at 6000 lbs. per sq. inch.

If $\frac{T}{10000} < \frac{C}{15000}$; or in other words, if the section required for compression for crushing is greater than for tension, then

$$\frac{C}{14000} + 0.7\,\frac{T}{10000}$$

gives me the section required for the fatigue of the material. Another condition is that the section be equal or greater than $\frac{T}{s_1}$ that is to say, that the member be able to resist crippling under the maximum compressive stress which may come upon it.

If on the other hand $\frac{T}{10000} > \frac{C}{15000}$, the required section will be $\frac{T}{10000} + 0.7 \frac{C}{15000}$ with a requirement for crippling as before.

Were I to take the usual method I would have for the required section $\frac{C + 0.7\ T}{s_1}$ or $\frac{T + 0.7\ C}{s}$, giving in both cases a much greater section and one in which my opinion is too great for long members. The above formula is empirical like other similar formulas.

But to return to the object and conclusion of Mr. Morison's paper. The experiments made by Mr. Morison have been made on bars of one particular grade of metal, of one particular shape and in one particular manner. Furthermore, the drilling of the hole left the section symmetrical. It is evident to me that in order to obtain results sufficiently reliable to lead to a change in general practice of deducting the full section of holes in tension members, we must first have a machine that will break the test pieces in only a fraction of the time which is taken for it now. The critical stresses in structures are generally applied in a fraction of a minute, or often in a fraction of a second. We should have a testing machine, therefore, which could apply the full breaking load gradually but rapidly, and at the same time register automatically the elongation, yield point and ultimate strength. When such a machine is constructed we should make tests on steel of various physical properties, on shapes, bars and plates, on symmetrical and unsymmetrical sections. The lack of symmetry in the sections, such as angles with a hole drilled in one of the flanges, may have a great deal of influence in modifying the yield point. The rapidity with which the stress is applied, the degree of ductility of the metal, may be so many additional factors in determining the exact behavior of the metal and its splices. Not until we have a complete series of experiments on the ideal machine suggested before will we be able to determine the effect of splicing, and not until then will we arrive at the actual factor of safety.

I agree with Mr. Morison that plate girders should be calculated by the moment of inertia, but I have been in the habit of deducting rivet holes by taking the least moment of inertia of the net section.

CLOSURE BY MR. G. S. MORISON.

It is not claimed that the experiments described in this paper give any unexpected or novel information. They are principally valuable as confirming probable results and as adding a little to information already belonging to the profession.

The conclusions reached in the paper, that on the basis of behavior under working stresses we should be justified in working the spliced bar up to the gross strain we should put on a solid bar, that on the basis of elastic limit we should be justified in working the spliced bar up to nearly seven-eighths the gross strain we should put on a solid bar, and that on the basis of ultimate strength we should be justified in working the spliced bar up to five-sixths the gross strain we should put on a solid bar, are only approximate conclusions, but are believed to be sufficiently close to absolute accuracy to justify following them in practice. It is admitted that the refinement of extreme accuracy might give somewhat different results. The practical application drawn from the first of these three is that in a riveted member the gross section may be used in determining the moment of inertia by which the member is to be proportioned. The practical application from the other two conclusions is that in determining working stresses, the stress on extreme fibers allowed for a built up section should be less than for a solid rolled section. The practice of the writer for some years has been to proportion all plate girders by the moment of inertia of gross section; to fix the limiting unit stress in extreme fibers for solid metal; and to reduce this stress in built members in proportion to the amount of metal removed by the rivet holes in the extreme flanges. In the case of girders with cover plates this reduction is easily determined; in the case of girders without cover plates a somewhat arbitrary rule must be followed, the idea being to make an allowance for rivet holes in the connection of the flange angles with the web corresponding to that made for rivet holes in cover plates and horizontal flanges of angles, if they exist. These experiments indicate that this allowance is larger than necessary.

IN MEMORY OF PROFESSOR NELSON OLIVER WHITNEY.

Nelson Oliver Whitney was born May 3, 1858, at Aiken, South Carolina, where his parents were temporarily located. He graduated at the Mantua Academy of Philadelphia in 1874, and from the civil engineering course of the University of Pennsylvania in 1878. During the summer following his graduation he was on the geodetic survey of Pennsylvania, and the next winter he was instructor in civil engineering in the University of Pennsylvania and in the Pennsylvania School of Industrial Art. From 1878 to 1880 he was in the office of the chief engineer of the Pennsylvania Railroad, where he was engaged in construction work. The next two years he spent in Mexico as locating engineer, under the late A. M. Wellington, on the Mexican National Railroad. In 1882 he returned to Pennsylvania and became locating engineer on the South Pennsylvania Railroad, and from 1884 to 1886 he was resident engineer on the Tuscarora tunnel.

In 1886 he was appointed assistant to the chief engineer of the Pennsylvania Railroad in charge of construction and maintenance at Chicago, which position he held until called to the chair of railway engineering at the University of Wisconsin in 1891.

The illness of Professor Whitney dates from November, 1899, when he contracted a severe cold while returning with his class from an inspection trip to Pittsburg. The cold soon developed into a severe attack of pneumonia, which was complicated by weakness of the heart, and it was only through the most careful nursing and watchfulness that the crisis was successfully passed. By February he had so far recovered as to be anxious to resume in a measure his University work, which he did by riding to and from his office in a carriage. But the exertion was too great, and in four or five weeks he suffered a severe relapse. In the course of the summer he gained gradually and seemed on the way to complete recovery. At the opening of the college year, in September, 1900, he again insisted upon doing a share of his work by meeting the students at his home. During the winter he continued to gain in strength, and it was hoped that he would be able to resume his work at the University. The announcement of his sudden death on March 17th, 1901, came as a great shock to his friends in the University and elsewhere.

Professor Whitney had that rare combination of personal qualities which enabled him to be equally efficient as a citizen, as an engineer and as a teacher, and in all these relations he made many strong personal friends. Apparently never in a hurry, he showed a quiet persistence and ability of execution that enabled him to accomplish his work with ease and efficiency. He had the practical man's horror of "rushing into print," and although he had a great amount of valuable material derived from his own experience which he gave his classes, he could never be persuaded to publish it. With him a difficult piece of construction successfully carried out, a railroad emergency quickly and skillfully met, or an army of workmen efficiently directed were the things which were to test the real merit of a man.

Professor Whitney alway insisted on work being well done. Students who shirked had little of his sympathy, but tasks assigned were almost without exception honestly and faithfully executed. As a teacher he was highly successful, and the influence of his high and noble character was strongly felt by all who came in contact with him. His interest in his boys continued as strong after their graduation as before, and it was a great pleasure to him to watch the career of those whom he had assisted in securing positions. The sadness of his death is intensified by the severance of those ideal family relations which he sustained to the wife of his love and the five beautiful and interesting children who had blessed their union, and who live to mourn his loss and revere his memory.

Committee—
J. B. JOHNSON, Chairman.
ISHAM RANDOLPH.
ONWARD BATES.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING, May 1st, 1901.

A regular meeting of the Society (No. 448) was held in the rooms on May 1st, 1901, Mr. O. Chanute, President, in the chair, with about fifty-five (55) members and guests present.

The minutes of the previous meetings were read and adopted.

Reports from the Board of Direction, on the election of new members, were read as follows:

Active Members—

L. P. Friestedt, 145 La Salle street, Chicago.
C. L. Hall, 1 W. Kinzie street, Chicago.
V. K. Hendricks, Terre Haute, Ind.
A. W. Merrick, Eagle Grove, Iowa.
R. E. McDonnell, Kansas City, Mo.
H. E. Stannard, Baraboo, Wis.
F. W. Hawks, Ellsworth building, Chicago.
L. P. Yale, 5520 Ohio street, Austin, Ill.
C. T. Dike, Peoria, Ill.
D. C. Rounseville, Kaukauna, Wis.
W. C. Armstrong, Boone, Iowa.
R. C. Sattley, Wheaton, Ill.

Junior Member—

A. S. Rosing, Buda, Ill.

And of those who had petitioned for membership, as follows:

Active—

J. G. Bergquist, Pullman Building, Chicago.
Geo. S. Rice, The Rookery, Chicago.
Geo. Adgate, Stock Exchange, Chicago.
Louis E. Ritter, Marquette building, Chicago.
Edward Murray, 81 Bryant avenue, Chicago.

Junior to Active—

M. K. Trumbull, 3600 Wabash avenue, Chicago.

Junior—

R. M. Geppert, Austin, Ill.
Condon Wray, 3035 Prairie avenue, Chicago.

On motion the reports were accepted.

A circular from the International Engineering Congress, to be held at Glasgow, Scotland, in the fall of 1901, was presented to the Society and read by title, and ordered posted in the Society rooms.

Mr. J. J. Reynolds offered an amendment to the by-laws, as follows: That to Section 3 of Article VI, under the heading of "Fees and Dues," following the words "Juniors, $5.00," shall be added, "of which dues $2.00 shall be set aside as subscription to the Journal." No action was taken on this amendment, as under the rules the matter had to lay over until the next regular meeting of the Society.

Mr. A. Bement, M. W. S. E., was then introduced, who presented by title his paper, which had already been printed and sent out in advance, on "A Simple Method of Determining the Conditions of Combustion, with Suggestions on Working Furnaces." This was discussed by Messrs. Breckenridge, Abbott, Gasche, Kerr and Bement.

Prof. L. P. Breckenridge, of the University of Illinois, M. W. S. E., was next introduced, who presented a paper on "Boiler Tests with Illinois Coals." This was illustrated by a number of lantern slides, and was discussed by Messrs. Guthrie, Bement, Sorge, Kerr, Rice, Merrill, Chamberlain and Abbott.

On motion of the Secretary a vote of thanks for their respective papers was tendered by the Society to Messrs. Bement and Breckenridge.

On motion of Mr. Finley the paper by Mr. G. S. Morrison, M. W. S. E., on "Effects of Splicing and Riveting," which had been listed for this evening, was postponed to another meeting.

The meeting then adjourned.

SPECIAL MEETING, May 8, 1901.

A special meeting (No. 449) was held May 8th in the Society rooms, with 125 members and guests present, Mr. W. H. Finley in the chair, who introduced Mr. A. V. Abbott, Chief Engineer of the Chicago Telephone Company, who addressed the meeting on "High Frequency Electrical Oscillations." This was illustrated by a number of beautiful and interesting experimental illustrations. This was a ladies' night, and after the address refreshments were served.

On motion a vote of thanks was tendered Mr. Abbott for his very entertaining and instructive lecture.

SPECIAL MEETING, May 15, 1901.

A special meeting (No. 450) was held on May 15th, President O. Chanute in the chair, and with sixty members and guests present.

Mr. J. H. Spengler, Assistant City Engineer, M. W. S. E., was introduced, who read an admirable paper on "The Water Works System of Chicago," which was illustrated by lantern slides and maps.

On motion of Mr. Finley, the discussion was postponed until another meeting.

The meeting then adjourned.

SPECIAL MEETING, May 22, 1901.

A special meeting (No. 451) was held in the Society rooms on May 22d, with Vice-President W. H. Finley in the chair, and sixty-three (63) members and guests present.

Mr. R. C. Sattley, M. W. S. E., was introduced, who presented a paper on "A Central Railway Terminal for Chicago," which was illustrated by lantern slides.

Discussion followed by Messrs. Tratman, Morehouse, Bremner, Shnable and Sattley.

The meeting then adjourned.

REGULAR MEETING, June 5, 1901.

A regular meeting (No. 452) of the Western Society of Engineers was held June 5, 1901, in the Society rooms.

The meeting was called to order at 8:30 p. m., with President O. Chanute in the chair, and sixty members and guests present.

The Secretary read the minutes of four previous meetings, held May 1st, 8th, 15th and 22d, which were duly approved.

On behalf of the Board of Direction the Secretary reported the election to membership in the Society, in the

Active Grade—

Geo. S Rice, 1134 Rookery.
Geo. Adgate, 734 Stock Exchange building.
Louis E. Ritter, 1336 Marquette building.
Edward Murray, 81 Bryant avenue.
M. K. Trumbull, 3600 Wabash avenue, from Junior Grade.

Junior Grade—

R. M. Geppert, 304 Baird avenue, Austin, Ill.
Condon Wray, 3035 Prairie avenue, Chicago.

Also applications have been received as follows:

Active Grade—

W. L. Abbott, 3213 Beacon street, Chicago.
Jas. B. Girand, Williams, Arizona.
Chas. B. Burdick, 1580 Old Colony building.
Barton J. Sweatt, Mason City, Iowa.
H. H. Jackman, 2177 Washington boulevard.
Chas. G. Ludlow, 21 W. Lake street.
Arthur V. Abbott, 817 Plaza hotel.

Associate Grade—

Dr. L. L. Hubbard, Houghton, Mich.

Junior Grade—

T. C. Phillips, 1580 Old Colony building.

Reports from standing committees were called for, but none were given.

Under the head of new business the Secretary reported, with reference to the amendment to the by-laws setting aside $2.00 from the dues of each member, as a subscription to the Journal, as presented at the last business meeting, that of 116 letter ballots received, 113 were in favor of the amendment and 3 negative. The motion for the amendment to the by-laws is therefore carried.

The Secretary announced the death of John McIntyre, one of our newly elected members, on May 20th, 1901.

A communication from the Chicago University was read, in which the Society was invited to be represented by a delegate at the decennial celebration to take place on the dates of June 14th to 18th inclusive. On motion of Mr. Barker the selection of the delegate was referred to the President.

Mr. Grant introduced a motion that the regular meetings of the Society for July and August be omitted unless called by the Board of Directors. Carried.

Upon the conclusion of this business the Chairman announced that the paper by Mr. Geo. S. Morison, on "The Effects of Splicing and Riveting," would be read by title, it having been printed and sent out in advance, and was open for discussion. The Secretary then read discussions of this paper as sent in by Prof. A. N. Talbot of the University of Illinois, and Mr. J. A. L. Waddell of Kansas City. Further discussion was presented by Mr. Ralph Modjeski of Chicago.

The Chairman then announced that the paper by Mr. John H. Spengler on "The Water Works System of Chicago," which had been presented to the Society on May 15th, was open for discussion. Mr. John Ericson, City Engineer, presented a lengthy written discussion of this paper, in which he dwelt largely upon the subject of water waste and the need of further extension of the water works system to meet the requirements in the southwestern part of the city of Chicago. This paper was illustrated by maps and diagrams on the walls and lantern slides, and proved full of interest.

Mr. Ericson was followed by further remarks from Messrs. Spengler, Cooley, Ashworth, Tratman and Chanute.

The meeting then adjourned.

SPECIAL MEETING, June 26, 1901.

A special meeting (No. 453) of the Western Society of Engineers was held June 26th, 1901, in the Society's rooms, with Mr. W. H. Finley, First Vice-President, in the chair.

Prof. B. E. Fernow, of the New York State School of Forestry, was introduced by the Chairman, who addressed the Society on "The Relation Between Forestry and Engineering." This lecture was illustrated with many lantern slides, and seemed to be highly appreciated by the audience, and discussion was offered by Messrs. Hill, Cooley, Grant, Randolph and Tratman.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

Minister of Public Works, Inspector General of Ports and Navigation, Buenos Aires, S. A , Reports, maps, etc., for the improvement of the Port of Rosario. 11 pamphlets and cases of maps.

State Engineer and Surveyor, New York, 2 vols., cloth, 1 case maps: 1 vol. Report of State Engineer and Surveyor, 1900. 1 vol. Report and 1 case maps. Report ditto on Barge Canal, 1901.

Spon & Chamberlain, New York, 1 vol., cloth, "Induction Coils," by Norrie.

Crosby Steam Gauge & Valve Co., Boston-Chicago, 1 vol., cloth, Catalogue of Gauges, Valves and other appliances.

Crosby Steam Gauge & Valve Co., 1 vol., leather, small handbook, "Practical Instructions for Using Steam Engine Indicators," etc., etc.

Massachusetts State Railroad Commissioners, 2 vols., cloth.
" Report of Board of R. R. Commissioners, Jan., 1901.
" Public Document No. 14.

Peninsular Portland Cement Co., Jackson, Mich., Trade Catalogue.

American Car & Foundry Co., Trade Catalogue, Structural Steel Hopper Cars, September, 1900.

Goheen Mfg. Co., Canton, Ohio, Trade Catalogue, "Impressions and Expressions regarding Protective Paint."

Henry B. Baker, Secretary State Board of Health, Michigan, 5 vols., cloth, Reports 1873, 1875, 1878, 1885. 1899.

C. C. Merridith, Secretary Monmouth Mining & Mfg. Co., Trade Catalogue, "Standard and Double Strength Sewer and Culvert Pipe."

Wm. Himrod, Secretary Commissioners of Water Works, Erie, Pa., 6 pamphlets, Annual Reports 1895 to 1900 inclusive.

Lawrence Water Board, Lawrence, Mass., 19 pamphlets; Annual Reports, 1877–1898.

Zeph. R. Forbes, Water Registrar, Water Board, Brookline, Mass., 6 pamphlets, Annual Reports 1885, 1887, 1898, 1899, 1900.

Water Commissioners, Binghamton, N. Y., 1 pamphlet, Annual Report, 1900.

League of American Municipalities, Des Moines, Iowa, Proceedings Fourth Annual Convention, 1900.

Kingsford Foundry & Machine Works, Oswego, N. Y., 1 pamphlet, Trade Catalogue, "Centrifugal Pumping Machinery."

Philadelphia Book Co., Philadelphia, Pa., 1 small handbook, leather bound, "Technical Gas Analysis," by Frank H. Bates, 1901.

Society of Engineers, 17 Victoria St., Westminster, S. W., London, England, "Transactions for 1900," P. F. Nursey, Secretary and Editor, 1 vol., cloth bound.

Ernest McCullough, Lewiston, Idaho, 1 pam., Municipal Public Works, 1900.

Frank H. Hitchcock, Washington, D. C., 1 pamphlet, Trade of the Philippine Islands, 1898.

Bertrand T. Wheeler, Supt. of Streets, Boston, 1 vol., cloth, Report Street Department, 1900, City of Boston.

Hendricks' Architectural, Engineering and Mechanical Directory, 1901, cloth. By purchase.

Richard Price Morgan, 1 pamphlet, University Studies, vol. 1, No. 2, "Decline of the Commerce of the Port of New York."

University of Kansas, Lawrence, Kan., 1 pamphlet, Catalogue 1900–1901.

" " Illinois, Urbana, Illinois, " " " " "

Purdue University, Lafayette, Ind., 1 pamphlet, " " "

Rose Polytechnic Institute, Terre Haute, Ind,, Catalogue 1900–1901.

Armour Institute of Technology, Chicago, Catalogue, 1900–1901.

University of Michigan, Calendar, 1900–1901.

University of Kansas, Bulletin, Kansas University Quarterly, October, 1900.

Michigan Engineer, 1 pamphlet, 1901.

J. H. Warder, Civil Service Commission of U. S., 5 pamphlets, Rules and Regulations.

" " Civil Service Commission, Chicago, 1 vol., cloth, 4th Annual Report, 1898.

" " Civil Service Commission, Chicago, 1 vol., paper, 5th Annual Report, 1899.

City of Chicago, Civil Service Commission, Chicago, 1 vol. cloth, 6th Annual Report, 1900.

E. A. Rossiter, Civil Service Commission, Chicago, 1 vol., paper, 2nd Annual Report, 1896.

" " Civil Service Commission, Chicago, 1 vol., cloth, 3rd Annual Report, 1897.

The Iowa Engineer, Ames, Iowa, Vol. 1, No. 1, June, 1901, 1 pamphlet.

Dr. U. O. B. Wingate, Secretary State Board of Health, Wisconsin, 1 vol., cloth, 18th Report, 1899–1900.

Hydraulic Engineer on Water Supply, Queensland, Australia, 1 pamphlet, 1900; 16th Annual Report.

Secretary American Society H. & V. Engineers, New York, 1 vol., cloth, Transactions American Society Heating & Ventilating Engineers, Vol. VI, 1900.

E. E. R. Tratman, 1 pamphlet, Consular Report, U. S. Printing Office.

" " 1 pamphlet, 1900, Annual Rept., Asso. Ontario Land Surveyors.

Engineers' Club, St. Louis, 1 pamphlet, 6th Annual Bulletin of Engineers' Club of St. Louis.

Chas. Hermany, Chief Engineer and Supt. Louisville Water Works, 37 pamphlets, File of Annual Reports of Louisville Water Works, 1861–1899.

D. Van Nostrand Co., 1 vol., cloth, Tunneling, by Chas. Prelini, C. E., 1901.

H. N. Elmer, M. W. S. E., 12 vols., cloth, bound volumes Sanitary Engineering, vols, 5–15 inclusive.

" " 40 vols., cloth, Annual Reports, Chief of Engineers, U. S. A.

" " 1 vol., cloth, Directory of C. B. & Q. R. R., Stations, Maps, etc., 1898.

" " 1 vol., half morocco, Illustrated Catalogue of Hardware Merchants, "John Pretzlaff Co.," Milwaukee.

" " 1 pamphlet, Report on Thames River Bridge, New London, Conn., by A. P. Bollar, 1890.

" " 23rd Annual Report, 1897, Inspection of Mines, Ohio.

" " 10th " " 1893, " " " Kentucky.

" " 15th " " 1891, Bureau of Labor Statistics, Ohio.

" " 3rd Biennial, 1889–1890, Dept. of Statistics, Indiana.

" " Lot of pamphlets, including 30 Nos. of "Stone."

Wm. S. Hancock, Railroad and Canal Reports, State of New Jersey, 1900, 1 vol., cloth.

Ohio State Board of Health, 2 vols., cloth, Reports for 1899 and 1900.

P. Blakiston's Son & Co., 1 vol., (III) cloth, Gas Lighting, by Chas. Hunt, 1900.

School of Practical Science, Toronto, Engineering Society, 5 pamphlets, '93–4, '94–5, '95–6, '97–8, 1900–1.

Norman W. Henley & Co., 1 vol., cloth, 1901, "Principles and Practice of Linear Perspective," by H. T. C. Kraus, C. E.

State Board of Health, New Jersey, 1 vol., cloth, 24th Annual Report, 1900.
U. S. Government Printing Office, book Geographic Names, 1 pamphlet, Special Report of U. S. Board on Geographic Names, Philippine Islands, May, 1901.
Wynkoop Kiersted, C. E., Kansas City, Mo., 1 pamphlet, 1900, "Relation of Subsiding Basin to Water Purification."
D. Van Nostrand Co., 1 book, bds., 1899, "A Primer of the Calculus," by E. Sherman Gould.

BOOK NOTES.

The Decline of the Commerce of the Port of New York. By Richard Price Morgan, M. W. S. E.

This paper forms the second number of "University Studies," printed by the University of Illinois. It is inspired by the conclusions of the report of the New York Commerce Commission to the Governor of that State in 1900:

"The decline in New York's commerce has been steady and continuous for many years; it has been more pronounced during recent years, and has now reached serious proportions in an actual loss of exports. This loss has been largely in exports of grain and flour. While New York has been steadily losing, Montreal, Boston, Newport News, and the Gulf ports of New Orleans and Galveston have made substantial gains."

This conclusion being confirmed by Mr. Morgan's study of the subject, by numerous documents and by his professional observation, he endeavored to elucidate the rationale of the fact, and he traces it to three principal causes.

1st. Change in the mode of transportation. So long as the canal continued the chief mode of transportation, New York held a virtual monopoly of the export trade, through her command of the best route and lowest summit across the Appalachian range. When the railroad era arrived, other Atlantic ports availed of this new mode of transportation to overcome the mountain ridges, and as it became perfected and cheapened, these cities commanded a larger percentage of the exports.

2nd. Change in the focal point of surplus grain production. As population has increased, more has been consumed at home, and the regions where a surplus which can be exported is raised has moved further west. Mr. Morgan shows that the surplus wheat is now more convenient to the Canadian transportation lines, and that the surplus corn is gradually becoming more eligible to the southerly Atlantic and to the Gulf ports. He appends a map to show this.

3rd. Undue terminal charges in New York. This is due to the partial survival of ancient organization, and is covered by an arbitrary charge which is deducted before prorating the railroad transportation rate. In connection with this, Mr. Morgan also shows that other cities—Philadelphia and Baltimore—are allowed differential rates, made effective in 1877 to compensate the advantages New York then possessed in ocean rates; that these differentials are now more effective against New York in consequence of the decline in railroad charges, and should be revised.

Mr. Morgan does not believe that a ship canal from the Lakes to New York would be a safe agency for reviving its commerce. He believes that the railway is the paramount agency which should be employed. He does not dwell upon the savings which might be effected by remodeling the methods through which exports and imports are handled while passing through that port. These are well worth serious consideration by its citizens. O. C.

Tunneling: A Practical Treatise. By Charles Prelini, C. E. With Additions by Charles S. Hill, C. E. 8vo, cloth, 311 pages, 150 illustrations. Price, $3.00. D. Van Nostrand Co., New York.

The author treats of the subject of tunneling in nearly all its phases without making the work too voluminous or too expensive. After giving a short description of the historical development of tunnel building, the author proceeds to discuss preliminary considerations, method and purpose of geological surveys, and methods of determining the center line and forms and dimensions of cross section. The subject of tools and machinery used in tunnel construction is briefly touched upon.

The actual construction of tunnels, from the large railroad tunnel through the mountain side to the small submarine tunnel constructed for the purpose of furnishing a pure water supply to a city located on the shores of some soft water lake, is then described, particular attention being given to method of excavating through various material, timbering or strutting, centers, lining, etc.

The author does not deal with theories, but describes the methods actually adopted in the construction of tunnels in various places.

The book, being principally intended for a text-book for a beginner, serves this purpose well, and has the advantage over the very few books on this subject in the English language of being up to date. It contains a number of illustrations, and deserves a place in the library of every engineer. J. E.

Technical Gas Analysis. By Frank H. Bates, San Francisco, Cal. Philadelphia Book Company, Philadelphia, Pa. Cloth, 4x6½ inches. Price, $1.00.

This book is designated as volume number one of the Industrial Gas Series which the author proposes to issue, and which are to comprise also volumes on the following subjects: Calorimetry; Fuel Economies; the Gas Engine and its Economies; and the Economical Production of Gas for Power Uses.

The work in question is a reprint of articles which appeared in the Journal of Electricity. The author calls attention in the preface to the value of gas analysis in most industrial works, and that its use enables the operator to determine the working conditions in iron, steel and glass works, the maintenance of boiler and furnace efficiency, and the testing of gas engines, by which means losses may be traced and remedied.

This little volume is especially suited to the requirements of the engineer who may not wish to acquire a considerable library treating of this most important branch of chemistry, but wishes a handy and concise work treating the subject in a manner that would be suited to his requirements.

Several pages are devoted to the subjects of collection of samples and methods of analysis.

The instruments described are the Orsat, Elliott and Hempel, and the method of procedure and manipulation for each is given, together with preparation and treatment of reagents.

The chapter on measurement of gases is especially clear and concise, and gives corrections for pressure, temperature and vapor tension. A. B.

Street Pavements and Paving Materials. A manual of city pavements, the methods and materials of their construction, for the use of students, engineers and city officials. By Geo. W. Tillson, C. E., M. A. S. C. E., Member American Society Municipal Improvements, etc., etc. John Wiley & Sons, New York. Price, $4.00. 8vo, cloth, pages xii-532. Illustrated.

This very interesting and instructive book on street paving begins by giving the reason for the existence of roads, and traces their history and gradual development from the first path across the country to more pretentious roads and highways, finally reaching our modern streets and boulevards.

The second chapter treats on stone used in road-making, and gives a complete description of the different kinds, with their advantages and disadvantages. The third chapter is devoted to asphalt, and this subject is treated very thoroughly, though with the widely differing theories of such men as Clifford Richardson and A. W. Dow. The author states that it is impossible at present to determine by chemical analysis alone whether or not a certain sample of asphalt will make a good paving material.

The next chapter deals with brick clays and the manufacture of paving brick, and an excellent and full description of the latter is given, showing the different steps of the process from beginning to end. The chapter on cement and concrete is very complete and calls attention to the necessity of long time tests of cements, giving examples of cases where a very superior cement would be rejected on a short test, which proved most satisfactory at the end of six months and a year while the reverse was true of other samples which showed good results on a short test.

The chapter on the Theory of Pavements treats of the different elements desirable in an ideal pavement, and gives some startling statistics concerning street openings in New York, the report of the Commissioner of Public Works showing that permits had been issued for making 59,000 separate openings in 1896, or one in every 40 feet of paved streets.

The difficulty of maintaining pavements in good condition under such circumstances is clearly shown, and the author makes some suggestions by which these conditions might be materially modified.

The different kinds of pavements are described in the next chapters, and a table is given showing the proper crown to be given for different widths of roadway. The crown recommended is much less than that in general use in Chicago, and would seem to be too flat for our conditions here, where a level grade is the rule.

Attention is called to the evil effect of illuminating gas on asphalt pavements, and demonstrates the fact that to leaky gas mains is due the poor condition of most of our asphalt streets.

A chapter on plans and specifications contains all the provisions that should be made in calling for bids on different kinds of paving, and will be appreciated by the engineer who may be engaged in street work.

The final chapters of the book treat of street railway construction, width of roadways and a description of asphalt plants.

The whole work shows the result of a great deal of research, while it is evident that the author is thoroughly familiar with his subject, as the book is eminently practical and will well repay a careful perusal. The book is well indexed. D. W. M.

Induction Coils and Coil Making. By H. S. Norrie (N. H. Schneider) xii-270 pages, 79 illustrations; 5x6½ inches. Cloth, $1.00. Spon & Chamberlain, 12 Cortlandt street, New York.

This work was evidently compiled for the purpose of giving practical information regarding the construction and operation of induction coils. The diagrams and details of construction are made perfectly clear to the practical man by well written descriptions accompanying each diagram. The work has been broadened since the first publication by the addition of a partial description of wireless telegraphy and a number of new diagrams. While the volume has little value as a scientific work, it gives all the information that one could wish for in the construction of induction coils, and is valuable as a reference for work of this class.

E.

The Relation of the Subsiding Basin to Water Purification, and Information Relating to Water Clarification. By Wynkoop Kiersted, M. Am. Soc. C. E., Kansas City, Mo. 8vo pamphlet, 32 pages, 5 illustrations.

This monograph on the use of subsidence reservoirs for the more or less thorough clarification of turbid waters from detrital rivers, is well written and should be of interest to engineers interested in water supplies.

The plan proposed of using a series of subsidence reservoirs, through which the raw water passes from one to another, at a slow rate of flow, has proved of much value in taking out of the water a great amount of silt before the water is passed to the filters, and thus saves the premature choking up of the filters.

The first step in the process proposed and used is for the influent water to be admitted at or near the bottom of one of the subsidence basins, and preferably near the center of the same. The basin gradually fills up, and when full the water flows over a wier in a separating wall, in a broad and shallow film, into the adjoining basin. From this second basin the water may be taken into a third basin if necessary. But the principle is to have the water flowing through the several basins at a slow speed, and flowing out of the basins at the top or surface, thus permitting the at least partial settlement of the suspended matter to the bottom of the basin, and generally below the plane of currents induced by the movement of the water.

The mud and silt which settles at the bottom of the basins can be readily flushed out at intervals by a suitable opening in the bottom, and thus reduce to a minimum the time that that basin may be out of service. There are doubtless many small water works through the western country which are supplied from a detrital river or stream where this system of subsidence basins could be installed to an advantage. The effluent water, after being freed of the greater part of the mud, etc., in suspension can then be put through filters, for further clarification and purification, before delivery into the city mains. W.

A Primer of the Calculus. By E. Sherman Gould, M. Am. Soc. of C. E. Van Nostrand's Science Series, No. 112. 16mo, bds., 50 cents. D. Van Nostrand Co., New York.

This little volume is aptly described by its name, and fills the niche for which it was designed in a very creditable manner.

The author in an exceedingly brief and simple way takes up the fundamental principles of the calculus by the method of infinitesimals as far as the differentials of algebraic functions of one independent variable and their corresponding integrals.

It is illustrated by numerous examples of such a practical nature as to enable the student to be on a working basis of the science almost from the start.

While of necessity very brief, the explanations are sufficiently full to enable one who has had the requisite preparation for the study of this science to easily grasp their import, and the examples are of a nature to arouse and sustain interest.

For those who have already received the usual college training in calculus, and for engineers, the book is of value as an aid in a quick review of the first principles of the science, and for its practical illustrations as applied to the computations of volumes, areas and of stresses in girders.

It consists of 122 pages of written matter and 24 full page figures illustrating the various problems. H. E. S.

The Principles and Practice of Linear Perspective. By Herman T. C. Kraus, C. E. 11½ x 15¾, cloth bound, 53 pages, including 14 plates of explanatory diagrams. Price $2.50. Norman W. Henley & Co. publishers, 132 Nassau street, New York.

This is a collection of simple problems in perspective drawing, with accompanying explanations. There is no attempt at a formal discussion of the subject, farther than to call attention to the fact that objects diminish with their distance from the eye, rapidly at first and more gradually as the distance increases. This is illustrated by a diagram, but might as well have been shown by recalling the fact that the tangent of an angle is diminished in similar ratio.

The book will no doubt be of use to persons who have no special technical training, if the reading matter does not interfere.

To persons accustomed to scientific discussions its value will be less than Professor Ware's admirable work on the subject.

Engineers will probably find the illustrations of geometric perspective of details useful. The ground which the book covers has been traversed so well in the past that it seem useless to go over it again, more especially as one hour's instruction by a perspective draughtsman is of so much more value than the study of any book on the subject.

It is hardly kind to criticise the English of a confessed foreigner, and yet, in print, slight defects in grammar, and the introduction of German-American sentence, detract from the good opinion which the illustrations merit.

Perspective is a simple art, when rightly taught, and fascinating in a high degree. Its simplicity makes the explanation of its laws rather difficult, and more trouble is given to the student by works on perspective than is ever spent in making pictures without them. One of the best discussions of this subject, however, is to be found in the Encyclopedia Britannica, copied therefrom into most modern cyclopedias, and containing all the necessary information for the student whose desire is simply to draw perspectives. P.

TRADE CATALOGUES.

Centrifugal Pumping Machinery. Kingsford Foundry & Machine Works, Oswego, N. Y.

This is one of the trade catalogues of this company (others of which pertain to boilers, engines, etc.), and relates to various types and combinations of Centrifugal Pumps. The paper and type are excellent, and the illustrations of the best class, show many forms of pumps and combinations suited for a variety of purposes. The customary tables are presented, showing the rating, speeds, capacity, etc., of the several sizes of pumps up to 60 inches, which means the diameter of the discharge opening. The shipping weights are shown up to the 24-inch size. Certain features in the design and construction of these pumps, permitting the ready examination of the interior of the pump for cleaning and repair, are excellent. The construction and weight of parts appear to have been well considered for the work to be done. The combination of electric motors, direct connected to the pump shaft, as shown in some of the illustrations, is a good combination for service when electric energy is readily available. W.

Air Compressors. The New York and Franklin Air Compressor Companies have issued a handsome new catalogue of Air Compressors of various types and sizes, as constructed at the company's works, Franklin, Pa. The New York office is at 95 Liberty street.

The illustrations include air compressors of large size with cross compound Corliss engines, and duplex or compound air cylinders; also with duplex steam linders or belt-driven, with compound air cylinders. These are of advantage in e larger sizes of machine, in which the air is compressed to a high pressure. An tercooler of good design and construction, independent of the compressor, is also shown.

Other types and of various sizes are shown and listed, including a vertical belt-driven machine of moderate size, which possesses some decided advantages. The air valves are of the Poppet style, and the design and construction of these is excellent, particularly the facility with which the valve with its seat and cage can be removed without taking off the cylinder head.

The use of compressed air is now so general for so many operations in the industrial arts, that the installing of an air compressor is more and more frequently a question to the factory manager, and to such, a study of this catalogue and correspondence with this company would doubtless be of advantage to the would-be buyer of air compression machinery. W.

Sewer Pipe—Specials and Fittings.

The catalogue of the Monmouth Mining & Manufacturing Company, of Monmouth, Ill., shows an extended line of manufactures of clay products, embracing straight and socket, vitrified sewer pipe, with all forms of branches, curves, ells and traps; also vitrified invert blocks of various sizes, to be used in the construction of brick sewers. These latter have some points of special merit. This company also make a line of hard-burned drain tile for the draining of farm lands, and give three pages of text relating to their use, with some tables, to assist in planning a drainage system for wet ground.

Fire clay products, as flue linings, stove pipe and fittings, thimbles and chimney tops, as well as regular and special shapes of fire brick, are shown and listed.

Vitrified wall copings and conduit pipe for electric wires are also shown.

A promising and interesting item of manufacture by this company is that of hard burned clay meter boxes, to protect yet afford ready access to meters placed on service pipes of a water works system. W

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THE WATER WORKS SYSTEM OF CHICAGO.

By J. H. Spengler, M. W. S. E., Ass't City Engineer, Chicago.

Read May 15, 1901.

As a result of the writer's close connection and extended experience with the operation and maintenance of the water works system of this city during the past five years, it occurred to him that a review of the development and growth of this system would, perhaps, give the members of this society a better knowledge of this important branch of the municipal service. The general public seems to have but a hazy idea as to the extent of the system—the number of pumping stations, the number and character of engines, boilers and other appurtenances that go to make up the various plants, the complicated pipe system, the location and extent of the tunnels and cribs by which the water of Lake Michigan is supplied to the various stations.

Streets may possibly not be properly kept in repair or cleaned, sewerage facilities may perhaps be inadequate, but so long as an ample and pure supply of water is furnished, the general public is compensated to a great extent for any deficiencies that may exist in other requisites of a municipality.

In its remarkable growth, both as to population and area, in the development of its manufactures, commerce, etc., Chicago stands out pre-eminent among American cities.

This unparalleled growth has at all times made it a difficult problem for the engineer to plan extensions and improvements on a scale commensurate with the needs of the people. The absorption of adjacent towns, and especially the annexation in 1889 of the towns of Hyde Park, Lake, Lake View and others, each with its independent water works, by which 126 square miles were added to the city, further complicated the system of Chicago as a whole.

It will be the purpose of this paper further on to dwell more particularly on the extensive additions and improvements that have been made to the water works system during the past five years under the immediate supervision of the present City Engineer, by which all parts of the city as far south as 107th street are now obtaining, for the first time, an ample and satisfactory supply of water.

The water tunnels with the various intakes have been written up rather extensively during the past year in several technical journals. No attempt will, therefore, be made at this time to give any details with reference to their construction.

Chicago, as an incorporated city, is 64 years old. By an act passed January 15, 1831, the county of Cook was organized. The town of Chicago came into existence in 1833, at which time the population was 350. Chicago as a city was incorporated March 3, 1837, and the first city officers were elected May 2 following.

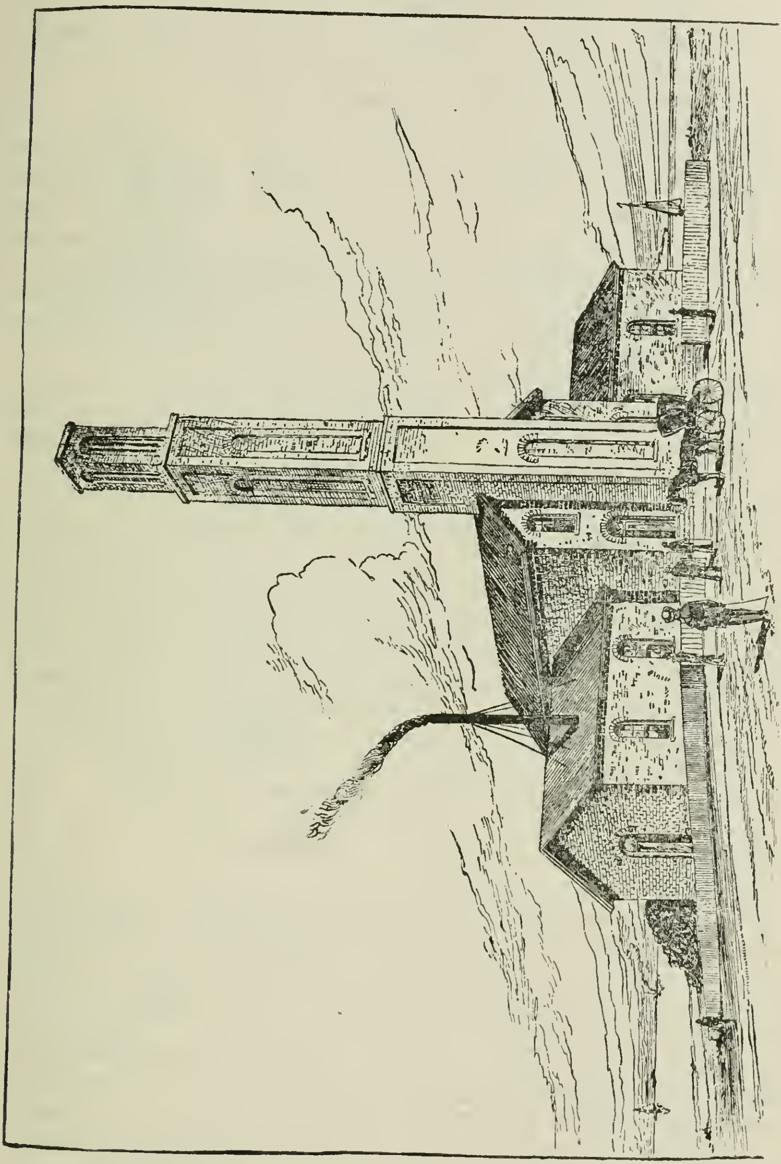
The earliest effort of which there is any record to provide a public water supply for the citizens of Chicago was November 10, 1834, when the Board of Trustees paid $95.50 for the digging of a well in Kinzie's addition. This well was located at what is now the intersection of Cass and Michigan streets. The settlers, however, soon realized that the lake was the most suitable source of water, and for some years private enterprise reaped a financial harvest in operating water carts for the supply of lake water to the citizens.

In January, 1836, the State Legislature passed a law incorporating the Chicago Hydraulic Company, and on March 10 following an organization was effected. The charter was to continue in force for a period of 70 years. The company had four years from the passage of the act in which to commence the construction of works. The panic of 1837, however, interfered with the affairs of the concern so that operations were not commenced until 1840. In this year the company built a reservoir at the corner of Lake street and Michigan avenue, 25 feet square and 8 feet deep, elevated about 80 feet above the surface of the ground, and erected a 25 horse-power engine, connecting it by an iron pipe with the lake, the pipe running into the lake about 150 feet.

The water was distributed through about two miles of wooden mains, these being logs bored at the works, 5 inches for the main lines and 3 inches for the subordinate ones. This supply reached but a small portion of the south and west divisions of the city. There was no supply from this source to the north division. At least four-fifths of the city, which then included about 10½ square miles, was supplied with water for domestic and other purposes from the river or by water cart system. The works of the Chicago Hydraulic Company were operated with varying success until 1852, during which year, as a result of a legislative act passed February 15, 1851, the rights and franchises of the company were taken over by the city and new works commenced.

In June, 1851, the Board of Water Commissioners employed

William J. McAlpine to make the necessary surveys for the works. Plans were later submitted and adopted. These were based on the estimate that at the end of fifteen years the population would be



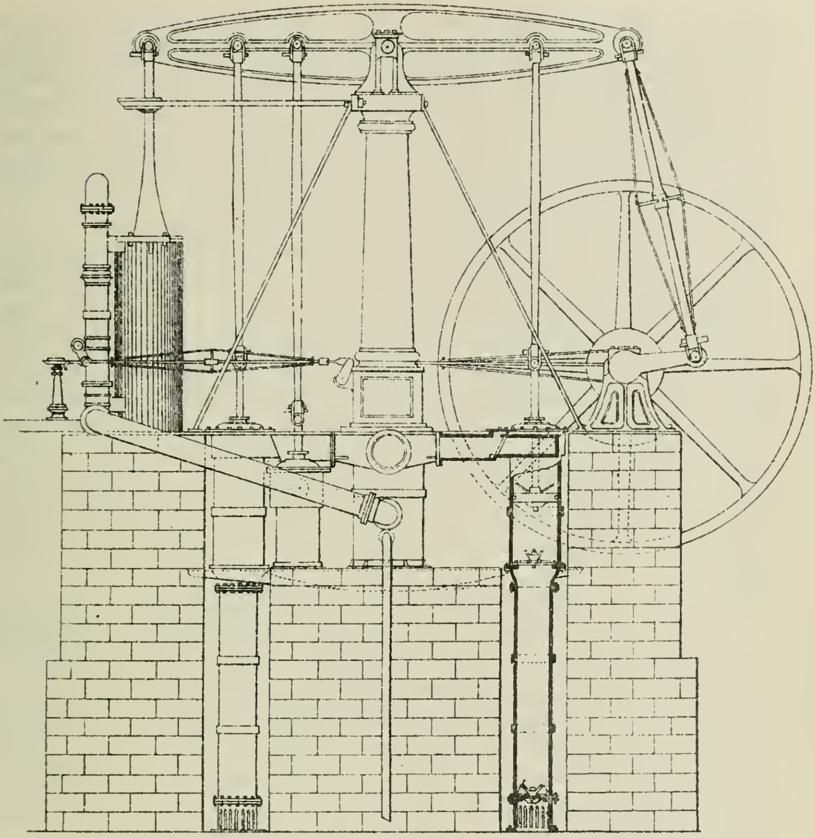
ORIGINAL WATER WORKS.

100,000. As a matter of fact, at the end of that period, 1866, the population was more than double that amount. The estimated cost of the work was $335,500. The annual expense of running them was estimated at $18,000. Following the plans and recommendations of the engineers, provision was made for a pumping station on the lake shore near Chicago avenue. A timber crib 20 by 40 feet was to be sunk 600 feet from the then shore line, and from this crib a wooden inlet pipe of 30 inches interior diameter was to be laid in a trench on the bottom of the lake to convey the water to the pump well placed in the engine house.

Work was commenced in the summer of 1852. The pump well was finished, a portion of the 30-inch inlet pipe was laid toward the lake, and the foundation of the building and tower put in, closing the work for the season. The following year the buildings and tower were finished, and several attempts were made to put in place the 30-inch wooden main. The boisterous condition of the lake rendered it difficult to secure the crib in place. The work was therefore finally abandoned and the water allowed to enter the pipe close to the shore.

During the same year the standpipe was put up and the engines erected. The main engine was started on December 16, 1853, and the supply of water for the city commenced February, 1854. The original pump well is rectangular, 20 x 30 feet, and 25 feet deep. The walls are of stone, 6 to 7 feet thick. Upon these walls the engines were located. The buildings were of brick, consisting of the engine room, 40 x 50 feet, and two wings for the boiler rooms, each 31½ x 40½ feet in the clear. The water tower was built of brick, 14 feet square at base, 11 feet at top and 140 feet high. The interior was divided by a wall, one part designed for a stack, the other for a cast iron standpipe 24 inches in diameter. The pumping machinery consisted of a vertical condensing beam engine, having a steam cylinder of 44 inches diameter and a stroke of 9 feet, with two single acting pumps of 34 inches diameter and 5½ feet stroke. The length of the walking beam is 30 feet. The diameter of the fly wheel is 24 feet, and the weight 12 tons. It has a capacity of 8,000,000 gallons per 24 hours. The cost of the engine and boilers was $24,500.

This condensing engine is working successfully and giving good service to this day. Working with a single steam cylinder under about 30 pounds steam pressure, it naturally is not economical compared with modern triple expansion engines working under a high initial steam pressure. The average daily working duty of this engine, known as the '53 engine, is less than 40,000,000 foot pounds per 100 pounds of coal, the consumption of coal being about 5 pounds per horse-power per hour. The water pumped was distributed through three reservoirs, located respectively at La Salle and Adams street, Chicago avenue and Sedgwick street, and Morgan and Monroe streets. The first two were built in 1853 and the latter in 1854, each holding about two or three days' supply.



Single Engine Erected in 1853—Chicago Avenue Pumping Station.

The first iron distribution pipe, 4 inches in diameter, was laid in Clark street in 1852.

As before stated, the supply of water commenced in February, 1854. During the first four months water was supplied but nine hours per day and none on Sunday, except in cases of fire. After that the supply was continued regularly throughout the twenty-four hours.

During the year 1855 a portion of the original 30-inch inlet pipe leading from the lake to the pump well was found defective, and a new one 3 x 4 feet square, made of oak plank, was put in at a greater depth.

During the early part of 1856 the quantity of water used in the city was nearly equal to the maximum capacity of the pumping machinery. A contract was made with the Morgan Iron Works, of New York, for the installation of an engine similar to the '53 engine, but of larger capacity. This engine, put into operation in July, 1857, has a single steam cylinder sixty inches in diameter with a stroke of 10 feet. There are two single acting pumps, each 40 inches diameter and 6¼ feet stroke. The length of the walking beam is 30 feet; the diameter of the fly wheel 24 feet, having a weight of 16 tons. The total cost of the engine and two boilers was $59,000. The capacity per twenty-four hours is 13 million gallons, and it also is in successful operation at this time.

In the report of the Board of Water Commissioners for the year ending March 31, 1858, we find that in order to keep the three reservoirs filled it was necessary to pump during about twelve and one-half hours each day. During 1858 two new reservoirs of half a million gallons capacity each were erected in the north and west divisions, one on Sangamon street near Monroe street, the other on Chicago avenue near Franklin street, and the distribution pipes were gradually extended all over the city, till at the close of the year 1862 there were nearly 105 miles in service. It appears that the use of these reservoirs had a favorable effect upon the operations of the pumping works, as well as upon the uniformity of the supply.

From this period up to 1863 the operations of the works were of an uniform and satisfactory character. During 1863 the daily average consumption of water reached nearly 7,000,000 gallons, and at certain periods a greater quantity.

In view of the rapid increase in population there was an urgent demand for an increased and adequate water supply.

I quote from Blanchard's History of Chicago, as to the agitation at this time relative to the necessity of an improvement in the water supply, both as to quantity and quality:

"Many suggestions were made and many plans submitted. Pipes along the lake shore, pipes out into the lake, filtering places along its margin, deep cuts from river to lake, fanning mills and Archimedean screws, pumps at Bridgeport, and numerous other schemes. All of these plans sought to cleanse the Chicago river from its accumulation of filth, and to provide an ample supply of pure drinking water. * * * Still other propositions were submitted as follows: To divert the water of the Calumet and Desplaines river into the Chicago river by means of a feeder and the use of pumps. * * * A second plan suggested was to build a series of intercepting sewers similar in their nature to those which had been built in the City of London for the purification of the river Thames. A ship canal as well as a covered aqueduct were proposed."

It was finally resolved that water should be taken from the lake, and on February 13, 1863, an amendment to the city charter was approved, by which power was given to the city "to construct such aqueducts along the shore of Lake Michigan, or in the highways or elsewhere in the said Cook County, and to construct such pumping works, breakwaters, subsidiary basins, filter beds and reservoirs, and to lay such water mains, and to make all other constructions in said county as shall be necessary in obtaining from Lake Michigan a sufficient supply of pure water for said city;" "to extend aqueducts or inlet pipes into Lake Michigan, so far as may be deemed necessary to insure a supply of pure water, and to erect a pier or piers in the navigable waters of said lake, for the making, preserving and working of said pipes or aqueducts." This action of the Legislature was sanctioned by Congress, January 16, 1864, and a tunnel under the lake was decided upon as the proper means for obtaining the requisite quantity and quality of water.

Construction of this first tunnel, extending from a shore shaft near Chicago avenue, northeast to a crib two miles out in the lake, was commenced March 17, 1864. The tunnel is 5 feet in diameter, and was first put in use March 25, 1867. It was calculated that with a head of 18 feet the tunnel would supply one million people with 57 gallons each per day. The total cost was $457,845. At this time (1867) the average daily supply was 11,562,273 gallons, with a maximum of 18 to 20 million gallons, and the population was about 240,000, the revenues being $337,468.00. There were 175 miles of distributing pipe.

Plans and specifications for a new engine, boilers, etc., were prepared in 1864, and the contract for same was let in July, 1864, to George W. Quintard, Morgan Iron Works, New York City. This addition to the plant involved the gradual demolition of the old building and the erection of a new and more commodious one, which forms the bulk of the North Side or Chicago avenue pumping station of to-day The plans for the new buildings provided ample room for this machinery, as well as for additional engines. The style of architecture is castellated Gothic, with heavy battlemented corners, executed in solid rock, faced ashlar stone and cut trimmings. The dimensions of the engine room are 142 feet long, 60 feet wide and 36 feet in the clear from the main floor to ceiling. A well for an additional engine was sunk in the south portion of the room. The outside diameter is 44 feet. Two boiler rooms, each 36 x 46½ feet, were constructed with a single smoke stack 130 feet high between them. A water tower, 154 feet high, was constructed west of the buildings. This contains a stand pipe 36 inches diameter and 138 feet high, having six openings at the base supplied with 30-inch gates.

The foundations and well for the new engine were commenced in 1866, and the engine first put into operation July 20, 1867. The buildings and water tower were finished early in 1869. The engine has a daily capacity of 18 million gallons, with two steam cylinders of 44 inches diameter by 8 feet stroke. The pumps are 28 inches diameter with 8 feet stroke. The length of each walking beam is

18 feet, weighing 7 tons. The diameter of the fly wheel is 24 feet and weighs 24 tons. The total cost of the engine, with one boiler, was $112,500.

A 4½ foot tunnel was constructed, connecting the new lake tunnel with the pump well. The machinery at this time had a capacity of 38 million gallons per day. The rapid growth of the city and the increased demand for water, per capita, soon necessitated the preparation of plans for an addition to the water supply. The Board of Public Works reported to the City Council, October 15, 1869, a comprehensive plan to meet the further wants of the city. This included the construction of an additional tunnel to start from the existing crib, to run parallel with the old tunnel to the Chicago avenue pumping station, thence in a straight line to some point on the south branch, not further east than Halsted street, nor further west than Ashland avenue. The diameter of this tunnel was to be 7 feet. Meanwhile, plans were made for a new engine to be installed in the south end of the existing station.

In July, 1870, a contract was awarded to the Fort Pitt Foundry Company, of Pittsburgh, for the construction and erection of a double engine, with a capacity of 36 million gallons in twenty-four hours. The well intended for the new machinery was constructed in 1868, without reference to the size or style of the engine to be built. The design of this engine necessitated the deepening of the well, which was accomplished in the following manner: The clay underlying the existing curb was excavated to a depth of 8½ feet below the shoe, and in order to guard against caving from sand pockets, etc., the excavation was made and the additional wall put in, in sections of about 6 feet in length. The wall is composed of a footing of stone 7 inches thick and 2 feet wide, upon which brick are laid in cement and are carried up to and connected with the curb of the cast iron shoe. Two courses of 3-inch oak plank laid in cement cover the entire bottom. Upon these, two courses of 12-inch oak timbers are laid 3 inches apart and the spaces filled with concrete. These timbers are covered with a course of 3-inch oak plank, making a total of 33 inches of solid oak forming the bottom. The tunnel from the gate chamber to the pump well was partly constructed in 1867, leaving about 25 feet to be completed. The completion of the well and the extension of the tunnel to the well was accomplished by October 9, 1871. The foundations for the new engines were at once constructed. They consist of two main piers and two sub-piers. The former are each 12 feet broad at the base, 6½ feet at the top and 24 feet long. The latter rest upon offsets in the main pier and are 10 feet square at the base and 8 feet square at the top.

On October 8th, 1871, occurred the great Chicago fire. It reached the pumping station the following morning. The buildings connected with the works were partially destroyed and the machinery disabled to such an extent that the pumps stopped working. The walls of the engine house were but little injured, while the roof, floors and other portions, including the machine shops connected with the works, were all destroyed. The '67 engine was again in running order eight days after the fire, and the other engines by November 10th. Several of the stone piers forming the engine foundations were so badly burned as to involve nearly entire reconstruction.

At the time of the fire the bed plates of the new engine were in place, but fortunately were uninjured, and the erection of the engine was prosecuted with vigor and completed November, 1872, and first put into operation the 14th of that month.

The steam cylinders are 70 inches diameter and 10 feet stroke. The steam chests are fitted with double balanced poppet valves of composition. The cylinders rest upon the upper plates, which are supported by four 9-inch columns extending from the lower plate. The walking beams are of cast iron, 26 feet between end centres, 6 feet deep in the middle and 2 feet at the ends. The beams weigh about twenty tons each. The main columns are 34 feet 7½ inches from base of pedestal to top of cap, and weigh 17 tons each. The columns serve as air vessels, being connected to a check valve chamber by a 30-inch wrought iron pipe. The fly wheel is 25 feet diameter and weighs 40 tons. The condenser is formed in the top section of the main column. The air pump is 45 inches diameter, 4½ feet stroke, and provided with rubber valves on composition seats. The pump chambers are 57 inches diameter, with 10 feet stroke, located directly under the steam cylinder. The pumps are double acting in their delivery, the plunger being solid for a portion of its length. The plunger is connected to and operated by the piston rod, 7¾ inches diameter, which passes through the bottom of cylinder. The working barrel of the pump is surrounded by an iron chamber, sufficiently large to make a channel for the delivery of the water discharged by the pump. The pumps are located below the surface of the water in the well. The upper end of the delivery chamber is provided with a circular nozzle, which is connected to a check valve chamber, having a double beat valve 36 inches diameter. To these chambers are connected the 36-inch discharge mains. The boilers (at present being replaced with new ones) are three in number, each 20 feet long, 12 feet in diameter, having sixty-six 5½-inch tubes. The entire cost of the engine and boilers was $188,400. The boiler pressure, per square inch, necessary to operate the four beam engines, is 30 pounds.

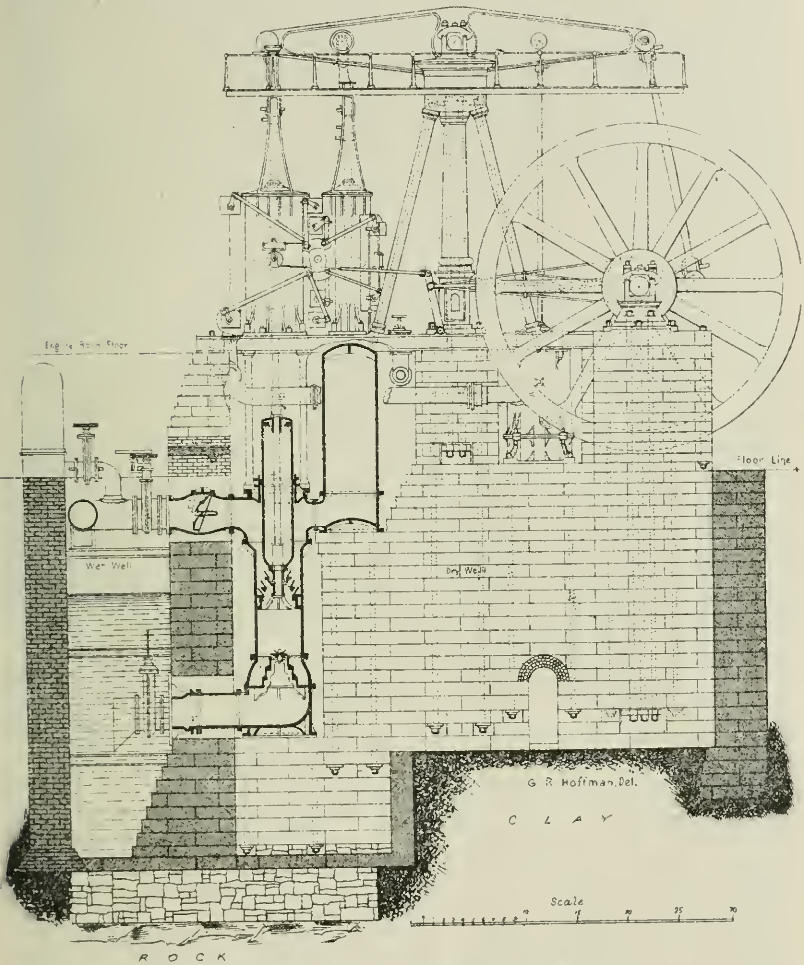
On July 12, 1872, in accordance with the recommendations made by the Board of Public Works in 1869, work was commenced on a second lake tunnel, extending from the existing crib to Chicago avenue station, and extending from that point across town to the present pumping station at 22nd street and Ashland avenue. The lake section is parallel with and 46 feet south of the first tunnel. Its diameter is 7 feet. The reasons for connecting with the old pumping station were as follows: 1st, To relieve the oldest pumps, the lift of which at times reached the limit, on account of the loss of head in the old tunnel, and to the increased pumpage. 2d, The saving in cost of pumpage by raising the water in the pump well. 3d, The great advantage of having two tunnels in case either one should need repairs or cleaning.

This lake tunnel was completed July 7, 1874, and the work on the land extension under another contract was commenced in July, 1873, and completed October 12, 1874. Its length, including the land extension, is 31,490 feet. The estimated velocity, when supplying 100 million gallons per day, was 4 feet per second. The total cost approximated $1,000,000.

Meanwhile work was commenced on the new pumping station at 22d street and Ashland avenue, designed to accommodate two new engines, and arranged to allow an addition to provide for additional engines in the future. The engine and boiler house is built of brick, faced with pressed brick and stone trimmings on the front. The engine room is 100 feet by 66 feet, and the boiler house 100 feet by 40 feet. The chimney is 125 feet high. The tower is 190 feet high from ground to top of masonry. The inside of the tower is cylindrical and 12 feet in diameter. The stand pipe inside the tower is 5 feet diameter, 167 feet high, connected originally to the discharge main from the engine with a 30-inch branch pipe on the west side of the tower, and with provision for a similar connection on the east side.

The foundations for the engines included a weir well, supply well and dry well. The weir well is semicircular in form, 26 feet in diameter. The land tunnel is connected with this well by a branch tunnel 7 feet in diameter. The supply well is 44 feet long by 10 feet wide, and separated from the weir well by a brick wall, at the bottom of which is a gate 5 feet by 3 feet (operated from the basement floor of the building) to admit water to the supply well. The foundations are built of large sized blocks of stones. The south part and the walls are built on the rock, which is 44½ feet below the surface of the ground. The north part of the foundations is built on blue clay, 29½ feet below the surface of the ground. The foundations of the buildings are on piles, except the west wall of the engine room, which is built on the wall of the wells, and the south wall, which, being temporary, was built on a foundation a few feet below the surface of the ground.

The contract for two compound condensing beam engines was let in 1875 to the Quintard Iron Works of New York. The general specifications for these engines provided that "each engine shall be capable of raising 15,000,000 U. S. gallons 155 feet high in 24 hours with a steam pressure on the boilers of 60 pounds per square inch, and develop a duty of 90,000,000 foot pounds based on 100 pounds anthracite coal." The boilers were to be three in number, any two to furnish the required steam.



1876 Engine—22nd Street and Ashland Avenue.

The engines were first put into operation November 6, 1876, thus increasing the pumping capacity of the water works to 104,000,000 gallons. They are so arranged so that they can be operated together or separately, connection being made by a cast iron coupling. The high pressure cylinders are 48 inches in diameter, with a stroke of 6 feet. The low pressure cylinders are 76 inches in diameter, with a stroke of 10 feet. Each walking beam is composed of two wrought iron plates 2½ inches thick, 36 feet long between centers of end pins and 7 feet deep at center. The plates are secured 15 inches apart by cast iron sockets and bolts running through and through. The beam pillow blocks are supported on two cast iron columns with four diagonal brace columns. Each fly wheel is of cast-iron, 32 feet diameter, weighing 60 tons. The condenser is placed below the bed plate, with the air pump inside the condenser, the hot well being in upper end of the condenser castings. The air pump is 38 inches in diameter and has 4½ feet stroke. Direct acting bucket and plunger water pumps are underneath the low pressure steam cylinders and connected with them by bolts and columns. The plungers are 36 inches diameter, with a 10-foot stroke. The pump chambers are 51 inches in diameter. The pumps are placed in the dry well. The suction nozzle is 3 feet in diameter and connects with the supply well. The delivery nozzle from each engine is 30 inches in diameter. The air chambers placed immediately behind the pumps are 16 feet high by 5 feet diameter. With the engines were installed six horizontal return tubular boilers, each 6½ feet diameter, 17 feet long, with 80 tubes 4 inches in diameter. The boilers are set up in pairs, and are supplied with water by independent steam pumps connected with hot wells, supply well and water mains. A formal duty and capacity test of the new engines was made in January, 1877, in accordance with the requirements of the specifications, with the result that the west engine developed a duty of 99,083,000 foot pounds with a capacity of 16,160,470 gallons in 24 hours. The east engine showed a duty of 96,066,800 foot pounds with a capacity of 15,571,970 gallons.

It might be interesting to note at this point that the average daily consumption of water during 1876 was 41,931,481 gallons. This, based on the population of 407,000, shows a daily consumption per capita of 106 gallons. The total number of miles of mains was 416.4, the number of house services or taps was 57,130, and the water revenue was $831,555. Number of hydrants, 2,901; stop valves, 2,590, and meters, 1,446. Total cost of water works, $8,179,158. The area of the city through successive extensions had increased to 36.66 square miles.

Before the great fire three reservoirs were in use, being respectively the centers of distribution for the north, south and west sides. That on the north side was located at Chicago avenue and Sedgwick street; the south reservoir was on the southeast corner of Adams and La Salle streets, and the west reservoir was on the southeast corner of Monroe and Morgan streets. They were wrought iron tanks, 60 feet in diameter, 28 feet high, resting upon stone and brick masonry, so that their tops were about 80 feet above the lake. Each contained about half a million gallons. They were finally abandoned, the last one (that on the west side) going out of existence in 1876, as they were then of little practical value to the water works system.

The pipe system as it existed at this time (1876) and for many years later was not the result of any carefully thought out or definite plan, formed at the inception of the works, but rather the result of a desperate attempt on the part of the engineers to keep up with the ever increasing demand and phenomenal growth of the city.

The most liberal estimates of increased population and territorial growth invariably fell far short of the reality. For many years, as fast as additions and improvements were planned to increase the supply, their completion found the city still facing the same old problem. Added to this was the uncertainty in which direction the greatest increase of population would occur, and what would be the demand for water in proportion to the population. Taking all these facts into consideration, the wonder is that the pipe system was as good as it was.

The original distribution system consisted of a 24-inch force main extending from the Chicago avenue station to North State street. From this point a 16-inch main passed along State street to Ontario street, and there reduced to 12 inches diameter. This size was continued south to the river, under which it passed after being enlarged to a 30-inch boiler iron pipe to connect with larger pipes in the future; thence a 12-inch cast iron pipe on State to Adams street; thence along Adams to the south reservoir; thence further along Adams street and under the South Branch by a wrought iron pipe, and along West Adams street to Union street; thence north to Monroe street. On Chicago avenue a 16-inch pipe was continued westward, connecting with the north reservoir, crossing the North Branch by a wrought iron syphon pipe to Union street; thence southward to Monroe street, where it united with the 12-inch pipe from the south reservoir, and thence along Monroe street to the west reservoir.

Hardly had the pumps of the new station been put into operation when attention was called by the engineers to the fact that the increase in population and the consequent increased consumption demanded additional pumping machinery. It was recommended that the original single beam engines installed in the Chicago avenue station in 1853 and 1857 be replaced with more modern engines of a larger capacity. As an alternative it was suggested that an addition be made to the Ashland avenue station large enough to provide for two more pumping engines similar in construction and capacity to those put into operation at this station in 1876.

During the month of January, 1879, the daily average pumpage was over 64,000,000 gallons, while the greatest amount for a single day, on the 4th of the same month, was nearly 74,000,000 gallons, and for several hours during that day the demand was at the rate of over 80,000,000 gallons. The population at this time being estimated at 450,000, the average quantity per capita pumped for the month above noted was 142 gallons. The City Engineer again recommended that it was absolutely necessary that immediate steps be taken to procure additional pumping machinery. A glance at the statement of the pumpage, pumping capacity, increase in population, etc., showed that "the annual average increased demand would, in all probability and in a very short time, leave but a limited margin of the available capacity."

Meanwhile plans were made for the construction of a brick tunnel, 9 ft.x6 ft. 6 in., under the South Branch of the river at Harrison street, through which a 36-inch main was to be extended west on Harrison street to Blue Island avenue; thence southwest to 12th street, with an ultimate further extension to 22d street and Ashland avenue, thus connecting the Chicago avenue and 22d street pumping stations. It was also designed to eventually continue a line of 36-inch pipe from the west pumping station southeast, connecting with the large mains in the south division; also due west to the city limits, the west limits at this time being Western avenue. The brick tunnel at Harrison street was built in 1880, and the extensions mentioned above were completed during 1881. During the same year a tunnel was constructed under the North Branch at Clybourn place, accommodating a 16-inch main, connecting mains of a like size on the east and west sides of the river. At the close of the year 1879 the mileage of water pipes of various sizes in use was 455½ miles; the number of valves was 3,105, and the number of hydrants was 3,361.

During 1881 the greatest quantity of water used for a single day (September 17) was 78,000,000 gallons, although the rate for several hours during this day marked as high as 83,000,000 gallons. This was within about 15 per cent of the maximum capacity of the two pumping stations.

The consumption of water reached 115 gallons per capita per day, estimating the population at 556,000.

In January, 1882, a contract for two additional engines each, with a capacity of 15,000,000 gallons, and to be installed in the addition to the west pumping station, was awarded to N. F. Palmer, Jr., & Co. of New York. These two engines, except as to the pump valves being of the double beat type, are practically duplicates of those installed in 1876, the plant including six tubular boilers, each 8 feet long, with shells 7 feet in diameter, with 68 tubes 4½ inches diameter, the total heating surface of each boiler being 2,454 square feet.

Each pump has 15 double beat or receiving valves, 12 double beat delivery valves in the annular space around the pump barrel of the same dimensions as the foot valves, and one 36-inch check valve located in the discharge nozzle from the pump.

The engines are compound condensing, with high pressure cylinder 48 inches diameter, by 6-foot stroke; low pressure cylinder

76 inches diameter, with 10-foot stroke; water pumps 52¼ inches diameter and of 10-foot stroke; air pumps 38 inches diameter, by 4.6-foot stroke; the fly wheels were 32 feet diameter, weighing 60 tons each; and the walking beams 38 feet long, weighing 32 tons each.

These two new engines were put into operation July 21, 1884, thus increasing the maximum capacity of the water works to 134,000,000 gallons daily. The entire cost of this addition in machinery, building, wet wells and pipe connections was $371,681.

The contract for these new engines called for a daily capacity of 15,000,000 gallons, each raised 150 feet high, with a piston speed not exceeding 200 feet per minute. The duty to be developed was 90,000,000 foot pounds for each 100 pounds of best quality eastern bituminous coal, the steam pressure at boilers not to exceed 70 pounds per square inch. An expert test of the two engines was made in April, 1885, the southwest or No. 51 engine developing a duty of 98,453,246 foot pounds under a head of 155 feet, with a delivery of 17,948,712 gallons per 24 hours; engine No. 52 showed a duty of 106,818,492 foot pounds, under a head of 157 feet, with a delivery of 18,088,198 gallons per 24 hours.

In the annual reports of the Commissioner of Public Works for the years 1883 and 1884 attention was called to the fact that, notwithstanding the increase in the pumping capacity due to the erection of two new engines, immediate consideration should be given to the limit of capacity of the water tunnels, which was nearly reached, and that in view of the unprecedented annual increase in population recommendation was made that additional pumping machinery should be placed at the Chicago avenue station, necessitating an additional water tunnel with an independent intake.

In October, 1885, a contract was let to the Holly Manufacturing Company of Lockport, N. Y., for two Gaskill horizontal compound condensing engines, each with a daily capacity of 12 million gallons, to be installed as an addition to the Chicago avenue station. The supply was to be obtained from the existing lake tunnels, through a 5-foot feeder tunnel extending from a shaft in the rear of the station to a wet well 12 feet in diameter placed between the two engines.

The specifications required that each engine was to deliver 12 million gallons per 24 hours under a maximum head of 150 feet above the surface of the water in suction well, with a piston speed not exceeding 120 feet per minute and a steam pressure not to exceed 80 pounds per square inch in the boilers. A duty of not less than 95 million pounds per 100 pounds of coal was to be developed.

The engines are of the compound condensing horizontal beam and fly wheel type. Each half of each engine has two steam cylinders situated in a vertical plane and parallel to each other, the high pressure being above the low pressure. The pistons being connected by short links to the short vertical beam at opposite ends, travel in opposite directions. The low pressure steam inlet valves are also the high pressure exhaust valves, and the low pressure exhaust valves are multiported on gridiron slides, worked by eccentrics from a lay shaft lying alongside the high pressure cylinder. The high pressure inlet valves are double beat poppets, operated by a "drop" cut off, adjustable by hand. The diameter of the high pressure cylinders is 27 inches; that of the low pressure cylinders is 54 inches and with a stroke of 40 inches. The diameter of the plungers is 30 inches. The fly wheel is 17 feet in diameter, weighing 22 tons. Steam is supplied to the engines from six horizontal return tubular boilers, in brick setting, each 66 inches diameter, eighteen feet long, with 66 4-inch tubes, the grate area being 26.25 square feet and the heating surface 182 square feet for each boiler. The height of the chimney constructed is 125 feet, with a diameter of 7.5 feet.

The engines were first put into operation in June, 1887, and an expert test made in October of the same year showed for the west engine a duty of 98,928,108 foot pounds when working under a head of 151.9 feet and pumping at a daily rate of 12,523,464. The east engine developed a duty of 102,583,585 foot pounds, the average head being 151.3 feet when pumping at the rate of 12,517,032 gallons per 24 hours. The total pumping capacity of the city at this time aggregated 158 million gallons per day. In 1886–1887 a third lake tunnel was built, of 7 feet inside diameter and 1,500 feet long, extending from the pumping station to a crib constructed to serve as a temporary intake to supply the "Chicago Avenue" engines when the supply from the crib was endangered by ice. At the new intake a shaft was sunk and fitted with gates to control the supply, the main supply being still drawn from the old tunnels. Later, in 1891, this tunnel was extended to an intake crib and shaft placed at the northwest end of the Government breakwater, a distance of 3,408 feet. This work was completed February 1, 1892. After its completion, however, the new intake was practically useless owing to the proximity of the intake to the shore, and its gates were rarely opened.

In order to meet the demands and provide for a reasonable supply of water, plans were made in 1887 for an additional tunnel system to supply two new pumping stations. These plans as finally developed comprehended a tunnel extending four miles under the lake nearly in line with 12th street to a new intake crib, to supply a new station located at 14th street and Indiana avenue and another at Harrison street between Desplaines and Halsted streets. The contract for the tunnel system was let November, 1887.

As finally completed this system consists of a lake section, comprising 9,139 feet of 8-foot tunnel and 25,200 feet of 6-foot tunnel.

The lake section ends at the Park Row shaft. From this point extend the two land tunnels. One of these is 7 feet in diameter, running north to the shaft sunk at Peck Court originally for the starting of the lake tunnel, and then northwest until it strikes the old 7-foot tunnel at Desplaines street. A shaft was sunk at this junction and a 6-foot tunnel driven to the new Harrison street pumping station. The second land tunnel, consisting of 516 feet of 8 feet in diameter, and 2,320 feet of 6 feet in diameter, extends from the Park Row shaft to the 14th street pumping station. In order to make proper connection with the old system of water tunnels, a 6-foot tunnel 625 feet long was built in Jefferson street.

On April 13, 1888, a contract was made with the E. P. Allis Company of Milwaukee for the installation of five vertical triple expansion engines, each with a daily capacity of 15,000,000 gallons, three to be placed in the 14th street station and two in the Harrison street station. Nine return tubular boilers were to be installed in the former station and six in the latter.

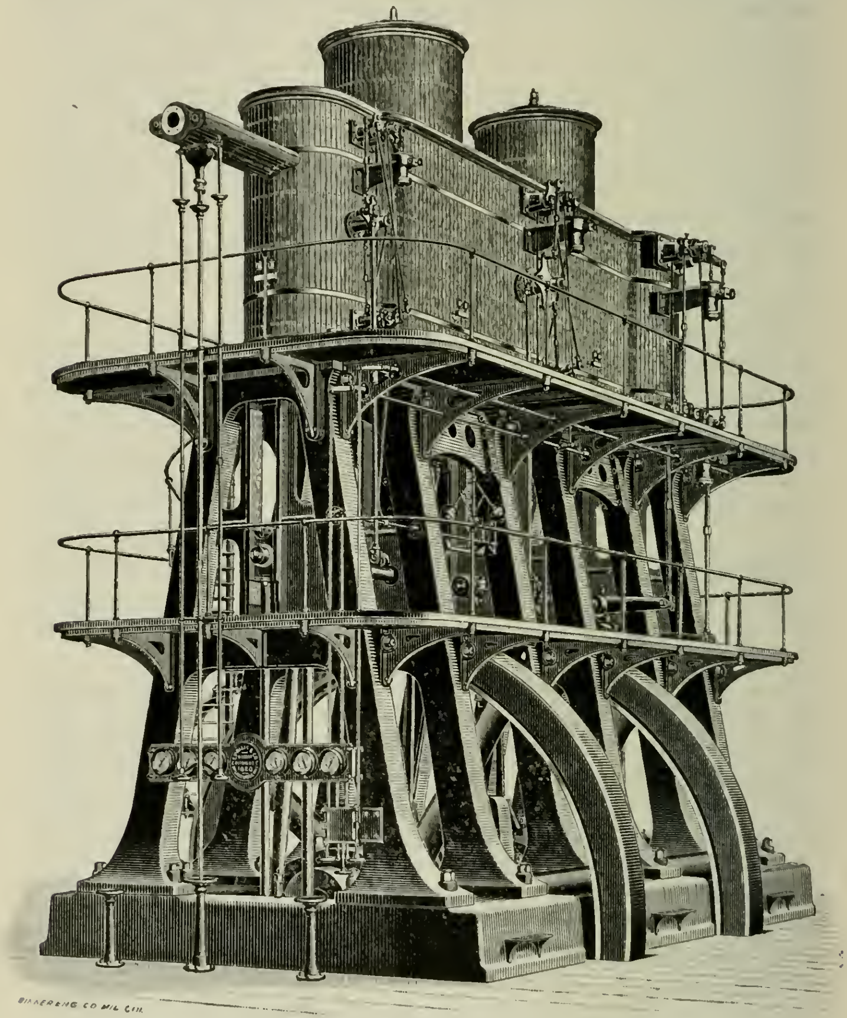
The same year one of the old boilers in the center boiler room at the Chicago avenue station was taken out and replaced by two horizontal tubular boilers 64 inches diameter, 18 feet long, each boiler containing sixty 4-inch tubes. These boilers were equipped with the Murphy automatic stoker and put into operation September 11th.

The four-mile tunnel system was completed December 7, 1892.

The Harrison street station commenced to give actual service July 14th, 1890. Until such time as the four-mile tunnel system was completed, water was obtained from the old seven-foot land tunnel connecting the Chicago avenue and 22d street stations. Only one engine as a rule could be supplied with water by this method.

The 14th street station, with its three engines and appurtenances, was completed during 1891. Pending the completion of the new lake tunnel, this station was at first temporarily supplied with water by means of the Jefferson street tunnel and the Park Row by-pass. This by-pass was constructed at the Park Row shaft, connecting the 7-foot tunnel north of it with the 6-foot tunnel south of it; the openings of the two tunnels into the shaft were closed by bulkheads. This arrangement enabled the contractor to use the Park Row shaft in connection with the construction of the lake tunnel. The by-pass was 6 feet in diameter and 196 feet long. When water was first turned on, the amount of percolation into the Park Row shaft was such as to preclude the use of the by-pass. It was subsequently lined with 3-16-inch steel, joined to the brickwork by Portland cement grout, put in under pressure. The supply to the station was admitted June 10, 1892. After this date such portion of the machinery was running as the supply of water would permit, but it became necessary to shut down altogether on account of the freshets in July, which compelled the absolute closing of the north shore inlet extension, so that no water could be spared for this station. After the water was admitted to the four-mile tunnel the engines at both of the new stations were run regularly, drawing their water from the four-mile crib.

The specifications of the engine and boiler plants for these new stations required that each engine should pump 15 million gallons per 24 hours against a head of 125 feet, steam pressure at boilers of 125 pounds, developing a duty of 125 million foot pounds per 1,000 pounds of steam. Two-thirds of the boiler capacity was to be sufficient to supply steam to the entire plant. With the full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The Allis Engines at 14th Street Pumping Station.

boiler capacity the engines were each required to deliver 18 million gallons per 24 hours.

The general dimensions of each engine are as follows: High pressure cylinder, 27 inches diameter; intermediate cylinder, 46 inches diameter; low pressure cylinder, 70 inches diameter; three single acting outside packed water plungers, each 32¾ inches diameter; stroke of steam pistons and plungers, 60 inches. The air pump is worked from the main engine, and has a diameter of 22 inches, with a stroke of 60 inches. The boilers supplied with these engines are of the return tubular type, and at the 14th street station are nine in number, each 62 feet by 20 feet, with forty-nine 4-inch tubes, and equipped with Hawley down-draft furnaces. At the Harrison street station six boilers of the same type and size were erected, but in this case were equipped with the Murphy smokeless furnaces.

On October 25, 1891, a formal test for capacity and duty was made at the Harrison street station. The result showed that when running with an average of 16.68 revolutions per minute, with steam pressure of 126.6 pounds, both engines delivered water at the rate of 31,534,043 gallons per 24 hours, against an average total head of 126.6 feet, showing a duty of 137,592,436 foot pounds per 1,000 pounds of steam, allowing 2 per cent for slip and leakage. The steam consumption was 12.67 pounds per indicated horse-power per hour.

The year 1889 was made memorable in the history of Chicago by the annexation of an extensive area to the original limits of Chicago. On June 29, by vote of the people, the city of Lake View and the towns of Hyde Park, Lake and Jefferson were annexed, thus increasing the area of Chicago 126 square miles, making the total area 170 square miles, the limits extending 24 miles north and south and 4½ to 10½ miles east and west. The population was increased by 220,000, making the total, as enumerated in 1890, 1,200,000. This increase in the territorial limits gave the city a frontage on Lake Michigan of 22 miles and a river frontage of about 58 miles for both sides. Through this annexation the city acquired two pumping stations—the 68th street station (the old Hyde Park and Town of Lake stations merged into one), and the Lake View station—with an aggregate engine capacity of 72,000,000 gallons per 24 hours; one lake tunnel 6 feet in diameter and 6,000 feet long, with a submerged intake for Hyde Park and Town of Lake; one lake tunnel in process of construction, 6 feet in diameter, for Lake View and Jefferson, and about 330 miles of water pipe of various sizes. The plant at Pullman was abandoned soon after annexation, and this district is supplied direct from the 68th street pumping station.

Later, successive annexations brought within the limits the water works plants of Washington Heights, Norwood Park, Rogers Park and Cicero. The two latter are still operated by private corporations.

The town of Lake View first built works in 1875, the system including direct pumping and pumping to two tanks 12 and 15 feet in diameter, the bottoms of the tanks being 16 feet above the level of the lake. The water was taken from the lake through two intake pipes about 2,000 feet long. The first pumping engine was a "Flanders" high pressure condensing, having two steam cylinders, each 15 inches in diameter, with a 15-inch stroke; two double acting pumping ends, with plungers 14 inches diameter and 20-inch stroke. The capacity was 2,500,000 gallons per 24 hours.

In 1884 the plant was increased by the erection of a Worthington duplex horizontal compound condensing engine, with a daily capacity of 5,000,000 gallons. This engine has two high pressure cylinders 21 inches diameter, two low pressure cylinders 36½ inches diameter, two pump plungers 22 inches diameter, all having a stroke of 36 inches.

In 1888 a Gaskill compound condensing engine was added, having a daily capacity of 12,000,000 gallons. The high pressure cylinders of this engine are 27 inches diameter; those of the low pressure, 54 inches, with water plungers 30 inches diameter and a stroke of 40 inches.

In order to provide a sufficient amount of water for future demands, and at the same time furnish a supply of satisfactory quality, a contract was let May 24, 1889, for the construction of a tunnel 6 feet in diameter, extending under the lake 5,000 feet and terminating in an intake crib. After annexation it was decided to extend the tunnel a mile further, so that the intake crib is practically two miles from shore.

At this time the water was obtained near the shore through four intake pipes from 16 to 30 inches in diameter. As the shore ends were not laid deep enough, at low stages of the lake the water supply became insufficient. To remedy this the shore end of the 30-inch pipe, which consisted of a wooden box 30 inches square, with its top one foot above city datum, was changed in 1891 to a steel pipe of the same construction as the lake end, and with its top lowered sufficiently, so that subsequently there was rarely a shortage.

Owing to the slow progress made on the tunnel, the poor quality and at times insufficient amount of water obtained through the intake pipes, and the trouble from ice in the winter, a temporary crib was placed over the tunnel about 6,000 feet from shore. This crib was provided with an intake shaft with gates. The water through this intake was first obtained April 6, 1892, and the old intake pipes abandoned.

During 1892 this station received an additional Gaskill 12,000,000 gallon compound condensing pumping engine, being practically a duplicate of the one installed in 1888. During 1892 an entire new building was constructed, enveloping the old one and providing sufficient room for the new engine and boilers. The old boilers were turned around and placed in line with the new ones, and all were equipped with the Hawley down-draft furnaces.

Annexation of the towns of Hyde Park and Lake added 53,000,000 gallons to the available pumping capacity of the city. These towns jointly first constructed a water works system in 1873. The station originally contained one Holly quadruple pumping engine, having a daily capacity of 2,000,000 gallons; also two Holly rotary engines and pumps, having a combined capacity of 2,000,000 gallons.

Lake water was obtained through a pipe 16 inches in diameter laid 1,000 feet into the lake, piles being driven around the outer end to protect the intake. Three tubular boilers 60 inches in diameter and 16 feet long furnished steam. In 1878 there was installed a Knowles horizontal compound condensing engine, having a daily capacity of 3,000,000 gallons. The steam cylinders were 24 and 37 inches in diameter, with plungers 20 inches diameter, and all of 36-inch stroke.

In July, 1882, the joint water works were separated, the town of Hyde Park building a pumping station of its own just west of the Town of Lake building. In this new station there was installed two Cope and Maxwell horizontal compound condensing engines, each having a capacity of 3,000,000 gallons, with four tubular boilers 60 inches diameter and 18 feet long. Each engine had high pressure cylinders 20 inches diameter, low pressure 40 inches, water plungers 17½ inches, all 36 inches stroke. These engines were abandoned and removed in 1898, being replaced by a new Holly engine.

In 1884–1885 a lake tunnel was constructed by the village of Hyde Park, terminating 5,036 feet from the shore shaft in a submerged intake. This tunnel not being completed in time to be utilized by the new Hyde Park engines, the tunnel was bulkheaded at the Yates avenue shaft, the two intake pipes were connected with this shaft, and that part of the completed tunnel between this shaft and the station supplied lake water by way of the old pipes to the new pumps.

In 1881 there was installed in the Town of Lake station two Holly vertical cross compound condensing engines, having a capacity of 4,000,000 gallons each, with four locomotive fire-box boilers, built by the C., R. I. & P. R. R. Co. Each engine had high and low pressure steam cylinders of 24 and 48 inches diameter respectively, and pump plungers 18 inches diameter, all having a stroke of 36 inches.

In July, 1885, lake water first flowed into the tunnel through the submerged intake. July 16, 1887, the Town of Lake connected the suction pipes of its station with the Hyde Park tunnel.

In 1885 the town of Hyde Park contracted for a 12,000,000 gallon horizontal high duty Gaskill engine. This pump was put into operation in July, 1886.

In 1889 Hyde Park contracted for a Worthington duplex horizontal high duty engine with a capacity of 12,000,000 gallons, supplied with steam from four 66-inch tubular boilers 18 feet long.

The general features of the engine involved two high pressure cylinders, 33 inches diameter; two low pressure, 66 inches diameter; plungers 33 inches diameter, with a stroke of 48 inches. The engine was put into operation in May, 1890. An expert test made March 12, 1891, showed a duty of 118,043,000 foot pounds, based on 100 pounds of coal, pumping at the rate of 12,582,600 gallons per 24 hours, against an average total head of 164 feet, and with a steam pressure of 75 pounds.

In February, 1889, the Town of Lake put into operation a horizontal compound condensing Gaskill engine of a capacity of 12 million gallons, being practically a duplicate of the one installed in 1886.

In 1891 an arrangement was made whereby the city was to install two additional 12 million gallon engines at this station in advance of ordinary needs, the pumpage of these engines to be entirely for the benefit of the World's Columbian Exposition, the Exposition Company to advance the funds needed for the new plant, to be repaid by the city at the close of the Exposition. In order to house these engines an addition was built on the south side of the Hyde Park station large enough to accommodate also the Town of Lake Gaskill engine, to be moved later. Contracts were accordingly let for two Gaskill horizontal compound condensing engines, with steam cylinders 30 and 54 inches in diameter, water plungers 31 inches in diameter and 40-inch stroke. Each engine was provided with four air pumps, with 20-inch plungers of 22-inch stroke. These were put into operation September 6th, 1892.

The Gaskill engine was removed from the Town of Lake station in the same year and placed adjacent to the engines just described. This pump was again put into operation February 17, 1893.

In 1892 it was decided to construct a 7-foot extension of the original tunnel to an intake crib two miles from shore. As the water supply for the Columbian Exposition was to be drawn from this tunnel, it was decided to place an intermediate crib and shaft 6,500 feet from shore, thus allowing the work to be prosecuted from three headings. The original plan was to build the new 7-foot tunnel westward from the new intake crib to a point near the submerged intake and then to connect the two. This would have necessitated pumping the water out of the old tunnel. To supply water to the pumps during this time a 5-foot shore tunnel was built, terminating at a crib 900 feet from the shore. As the 7-foot tunnel could not be completed in time for the Exposition, the plan of connecting with the old tunnel was abandoned. The shore tunnel was meanwhile extended 600 feet farther to a temporary intake crib 1,500 feet from shore. This was then extended with a view of connecting it with the 7-foot tunnel. The new system was completed in June, 1894, and the 68th street station consequently received its supply through the old 6-foot tunnel from the submerged intake, and through the 7-foot and 5-foot tunnels from the new two-mile-crib.

On November 4, 1890, through annexation, the Washington Heights pumping station, located at 104th street and Vincennes avenue, was added to the city. This station was built in 1885, and in it was installed a Smith-Vaile pump of 400,000 gallons capacity, also a deep well pump, the water being obtained from an artesian well 1,350 feet deep. The water was first pumped into a cistern, and from there forced into a wooden tank 30 feet in diameter and 20 feet deep, placed on posts 60 feet high. The tank is located about one mile from the station on the high ground. The water was distributed through about 17 miles of mains 6 to 8 inches in diameter. In 1892 this station was enlarged. A new building was erected over and around the old one, large enough to receive additional pumping machinery in the future. The same year a new Fairbanks & Morse pump of one million gallons capacity, and one 60 horse power tubular boiler, were added to the plant. In 1893 the capacity of this deep well pump was increased by replacing the old 6-inch cylinder by a new one 10¼ inches in diameter. The normal level of the water in the well having gradually lowered on account of the increased demand for water, it became necessary in 1895 to supplement the well supply with lake water. A cistern was connected with the street main, through which water was delivered from the 68th street pumping station.

The village of Norwood Park became annexed November 7, 1893. This suburb is supplied with water from an artesian well 1,600 feet deep, the plant consisting at that time of the following: One Deane duplex pump 9 x 5¼ x 10 inches, capacity of 250,000 gallons; one 36-inch tubular boiler 10 feet long; a stand pipe, consisting of a brick tower about 60 feet high and 12 feet in diameter, on the top of which rests a wooden tank about the same diameter and 36 feet high. These works were built in 1889.

On April 4, 1893, the village of Rogers Park was annexed. The water works of this district are still operated by the Rogers Park Water Company. They were built in 1889, being put into operation August 15th of that year. The franchise term under which these works were constructed, and are being maintained and operated, is for 30 years from the day the works commenced to operate. Under the franchise, the City of Chicago has an option to purchase this system ten years after the same commenced to operate, and at each five years thereafter. The city is to give the company notice of its intention to exercise its option six months before the expiration of any one of the periods of time at which the option matures. The value of the plant is to be obtained by a board of three non-resident appraisers.

The source of supply of the system is Lake Michigan. It is taken through an intake pipe which extends 3,200 feet into the lake and is 20 inches in diameter. The machinery consists of two compound engines, manufactured by the Deane Steam Pump Company, Holyoke, Mass., which have a capacity of 1 ½ million gallons each. Four filters of a capacity of one million gallons per day are used. They are of the pressure type, as now manufactured by the New York Continental-Jewel Filtration Company. The stand pipe is 125 feet in height, 12 feet in diameter, and has a capacity of 125,000 gallons. The water is pumped to the stand pipe, except in case of fire, when the stand pipe is cut out and the direct pressure system used. The distribution system consists at present of 20 miles of main, varying in size from 12 to 6 inches. The average consumption per day at this time is about 400,000 gallons, with a maximum pumpage of one million gallons. The pressure maintained is ordinarily about 55 pounds.

The annexation of the large territory in 1889 and 1890, and the acquisition of the several pumping stations already described, with the inadequate pipe systems of the several towns and villages, greatly complicated the water supply situation. As the pumping stations were all located along the lake shore, water had to be pumped for miles through mains which were laid necessarily without regard to the new conditions and demands that had arisen. The pipes were too small, and the necessity of additional large feeder mains was imperative in order to insure a proper distribution of the water as furnished by the pumping machinery. The annual increase in population and manufactures was far beyond expectations. The additional machinery that had been placed during 1892 in the Lake View and 68th street pumping stations, and the opening of the 14th street and Harrison street stations in connection with the new four-mile lake and land tunnel system, failed to give relief to certain portions of the city. The pumps were forced to pump against a higher head than should have been necessary. The average daily pumpage during 1894 was 238,521,280 gallons, or 152 gallons per capita. The greatest amount pumped in one day was 276,886,135 gallons. The pumping capacity at this time was 357,000,000 gallons. Notwithstanding this large pumpage, the City Engineer reported that in the south end of Lake View, and on the north side, west of Lincoln Park, the pressure of water was very low. The north end of Hyde Park was in a similar condition. In the western portion of the city, extending from the extreme north to the extreme south, there was suffering from lack of an adequate supply, especially in hot weather. To relieve these conditions, which were rapidly becoming worse, the City Engineer recommended the placing of additional machinery in the Lake View and 68th street stations, and the construction of a new tunnel system to feed water to new stations to be located near the western limits of the city.

On January 24, 1895, the City Council ordered: "That the Commissioner of Public Works be, and he is hereby authorized and directed to make estimates and advertise for bids, and let contracts for the extension of the north shore inlet, and the construction of a tunnel to Garfield boulevard and West 46th street, or to such points as he may designate; also for the construction of a tunnel in the northwestern section of the city, in the neighborhood of Fullerton avenue. The amount to be paid for such work annually not to exceed $500,000."

On March 30, 1896, authority was given for a lake tunnel, including an intake crib necessary to feed the proposed land tunnels. The appropriation for the lake section, including shafts and cribs, was $774,500.

On March 15, 1897, authority was granted for the construction of two new pumping stations in connection with the new tunnel system. The plans for this new system, in accordance with which the land and lake tunnels were completed, was as follows:

The entire system was divided for contract purposes into four sections. The lake section, known as the "Northeast Lake Tunnel," extends from a shaft at the foot of Oak street northeasterly to a new intake called the Carter H. Harrison crib. Its length is 14,033 feet, with an internal diameter of 10 feet. The contract was let July 6, 1896, and the tunnel was completed in January, 1899. The entire crib was completed in November, 1899. The cost of the lake section, including the crib, was $590,000. Of this amount, $225,000 was expended on the intake crib, being $250,000 less than the total cost of the four-mile crib, heretofore considered the most complete crib in use. The new crib is sunk in 35 feet of water, the outside diameter being 112 feet, with a well in the center 62 feet in diameter. Six ports, each 5½ feet by 5½ feet, located near the bottom, allow the water to enter the well. Within the well there is sunk an intake shaft about 100 feet deep. The upper part of this shaft is a cast iron cylinder, 2½ inches thick and 12 feet outside diameter, provided with three gates with necessary screens, the gates being only a few feet below Chicago datum. The top of the cylinder is 8 feet above datum. Below the cylinder the shaft was constructed by the underpinning process, that portion being 11 feet inside diameter and lined with four rings of brickwork. A second intake shaft was put into the well of this crib immediately after the completion of the first one. These two intake shafts are entirely alike, both as to diameter and depth, as well as in manner of construction.

From this second shaft a stub tunnel 100 feet in length and 10 feet internal diameter was constructed. This second shaft is intended as a future intake for the three tunnels at present receiving lake water from the original two-mile crib.

The land system through which lake water is supplied to the new pumping station is divided into three sections. Section 1, 10 feet internal diameter, extends from the Oak street shaft, the western terminus of the lake tunnel, to Green street and Grand avenue, a total distance of 8,666 feet. From this latter point the main feeder divides into two auxiliary tunnels, each 8 feet in diameter, one extending southwesterly to a suction well at the Central Park avenue pumping station, located at Central Park avenue and Fillmore street; the other running northwesterly to the Springfield avenue pumping station, located at Springfield avenue and Bloomingdale road. The former, known as section 2, is 19,856 feet in length, of which 9,894 feet was constructed through earth and 9,962 feet was through solid rock. The latter, characterized as section 3, is 22,184 feet in length, of which 3,211 feet was constructed in earth, 3,464 feet through part earth and part rock, and 15,509 feet through solid rock.

The lake tunnel was completed in January, 1899. Section 1 of the land tunnel system was finished April, 1897, and sections 2 and 3 early in 1900.

Meanwhile, other improvements and extensions to the existing tunnel system were in progress. The 7-foot shore tunnel, running easterly from the Chicago avenue pumping station, which in 1891 was extended to the northeast end of the Government breakwater, was, since its completion, practically useless, due to the close proximity of the intake to the shore. The two old tunnels terminating at the two-mile crib had been taxed to their utmost capacity, and in order to utilize the tunnel terminating at the breakwater and relieve the old ones, it was decided in 1895 to extend the former to the two-mile crib. A contract for this extension was made August 22, 1895. Owing to the insufficient port area and the small size of the well at the two-mile crib, a new intake shaft was sunk between the crib proper and its protection breakwater, protected with a pile crib filled with rip-rap. Water was let into this extension July 21, 1896, thus providing a third tunnel from the two-mile crib to the Chicago avenue pumping station, with necessary connections in order to reinforce the supply to the 22d street station.

The capacity of the 5-foot tunnel of the 68th street system being insufficient, it became necessary to draw part of the supply required by the 68th street pumping station from the 6-foot tunnel leading to the submerged intake, although this intake was considered to be too near shore for safety. Accordingly, on the recommendation of the City Engineer, a contract was let for the construction of about 5,000 feet of 7-foot tunnel from a shaft located at the intersection of 68th street and Yates avenue to the stub end of the existing end of the 7-foot tunnel running westward from the two-mile crib. This extension was continued by means of a 5-foot tunnel from the shore shaft to the existing Yates avenue shaft at the 68th street pumping station, and was completed May 21, 1898. The total number of lineal feet of 7-foot tunnel constructed under this contract was 7,316; in addition, there was built 102 lineal feet of 5-foot tunnel. The entire water supply for the 68th street pumping station is now taken from the tunnels receiving lake water by way of the 68th street crib. The original submerged intake is permanently abandoned.

Contracts for the two new pumping stations in connection with the new lake and land tunnel system were let April 14, 1897. The buildings are practically duplicates and are constructed of pressed brick and terra cotta, with steel trusses and tile roof. The engine room is 83 x 100, the engine pit being the full size of the room. The floor on which the engine rests is 18 feet below datum. From an iron balcony 6 feet wide, and placed at about the street level, access is had by means of a circular stairway to the bottom of the engine pit. Each station has one smoke stack, 175 feet high, the flue being 9 feet in diameter. The retaining walls of the engine pit are constructed of block rubble stone laid in Portland cement mortar on a concrete base; the top is 4 feet wide and the width at the base is 17 feet. At the Springfield avenue station these walls rest directly on the solid rock. At the Central Park avenue station the base of the walls is founded on a hard indurated clay.

January 23, 1897, a contract was let to Henry R. Worthington, of Brooklyn, N. Y., for the furnishing of six vertical triple expansion pumping engines, each with a daily capacity of 20,000,000 gallons, three to be installed in each station, steam to be supplied in each case by six horizontal return tubular boilers. The general design and features of these engines as erected are as follows: The engines are fitted with the well-known Worthington high duty attachments, enabling a high rate of steam expansion to be maintained without regard to the piston speed, also insuring an easy flow of water to the mains and acting as a safety device, causing the engine to come to a state of rest without damage in case of a break in the water main. There are two high pressure, two intermediate and two low pressure steam cylinders, with diameters of 21, 33 and 60 inches respectively. Two reheaters, 27 inches by 2 feet 6 inches, and 27 inches by 4 feet, are provided. Each engine has two double-acting pumps, there being 54 valves in the suction chamber and the same in the discharge chamber. The plungers are outside packed, 34½ inches in diameter and 8 feet 9 inches long. Each engine has one surface condenser placed on the suction pipe. The stroke is 4.1 feet. Each engine is designed and constructed to deliver 20 million gallons per 24 hours at a plunger speed not exceeding 150 feet per minute, and against a head of 150 feet, with steam pressure at the boilers of 140 pounds per square inch. Under these conditions the engines are to develop a duty of not less than 135 million foot pounds per 1,000 pounds of steam. The suction pipes of the engines are connected with a wet well, the foot valves of these pipes being at 30 feet below datum. The wet well is simply a continuation of the 10-foot shaft to which the tunnel is connected. This shaft is enlarged at a point 35 feet below datum to an elliptical shape about 22 x 25 feet. This enlarged shaft is carried to the level of the floor of the engine pit. Above this point the well is constructed of steel plates 5-16 inch thick and lined with three rings of brickwork, the base being a 6 x 6 angle resting on and bolted to the brickwork at the level of the engine room floor.

The boilers, each of 250 horse power, are of the internally fired horizontal return tubular type, 10 feet in diameter and 12 feet long, designed to carry a working pressure of two hundred pounds, provided with Morrison corrugated furnace flues, and each boiler having attached a Hawley down draft furnace. The boiler room is also provided with water purifiers, auxiliary feed water heaters and high pressure feed pumps. Each station is equipped with a complete coal conveying plant, by which the coal is taken from the cars, crushed and delivered in front of the furnaces, the ashes meanwhile being taken to a hopper in the coal room and dumped into cars for removal.

The conveyor is of the endless chain pattern with gravity buckets made of malleable iron. The buckets are made with an overlapping lip suspended between two chains and driven by a self-contained double cylinder engine and conveyor motor, taking steam from the regular boiler plant. Automatic dumping cams are placed over the coal and ash bins and arranged so as to properly distribute the coal at various points on the line of the conveyor. The coal bunkers have a capacity of 500 tons, and are provided with movable weighing hoppers which take the coal from any point under the bins and transfer the same to any point in front of the boilers. These hoppers have cut-off valves and self-contained scales.

Each station is also equipped with an electric traveling crane of 15 tons capacity, two bilge pumps, a 25 horse power electric light engine and generator, and a complete steam heating system.

The Central Park avenue station was first put into service June 28, 1900, since which time two engines have been operating continuously. Since the early part of January, 1901, one engine has been running at the Springfield avenue pumping station.

The results of the opening of these two stations had at once a marked effect on the water pressure along the western limits of the city.

Early in 1897 it became apparent that, notwithstanding the ultimate increase in the pumping capacity through the construction of two new stations, additions and alterations would have to be made to the machinery in the various stations in order to give satisfactory service. An exhaustive examination of all the pumping plants at this time developed the fact that, through a practice of false economy in the previous years, necessary repairs to the different engines had not been made, with the result that a majority of the engines were not pumping the amount of water as figured from plunger displacement. The boilers were also in bad condition. Owing to the great demand for water and the many complaints on account of insufficient pressure, which called for the operation of practically the full equipment in all the stations, but little could be done during 1897 to remedy defects and do necessary overhauling. In order to have reserve machinery, plans were made in 1897 for installation of additional engines in the Lake View, 14th street and 68th street stations. Upon the completion of these new engines the machinery in all the stations was thoroughly overhauled, involving the placing of about 25,000 new pump valves and the retubing of about 50 boilers. A large amount of pipe on both engines and boilers was renewed and remodeled. All the auxiliary machinery was overhauled and put into proper condition. The efficiency of the various plants was thus greatly increased and a consequent marked decrease in the cost of operation effected. The contract for a 14 million gallon additional engine to take the place of the Flanders engine at the Lake View station was let January 27, 1897, to the Holly Mfg. Co. of Lockport, N. Y. This engine is horizontal, of the compound direct-acting crank and fly wheel type, with outside packed plunger pumps, having two high pressure and two low pressure steam cylinders, the high and low pressure cylinders being connected to each plunger and by a connecting rod to the cranks of the fly wheel shaft. All steam and exhaust valves are placed in the cylinder heads. The cut-offs of the high pressure cylinders are controlled by a governor, while the cut-offs of the low pressure are adjustable.

The air pumps are connected directly to the walking beams. The steam cylinders are 30 and 54 inches and the pump plungers 32 inches in diameter, all with a stroke of 40 inches. Steam is supplied from two horizontal tubular boilers 66 inches in diameter, 18 feet long, with 108 4-inch tubes. They are equipped with Hawley down draft furnaces.

The contract required the engine to develop a duty of 110 million foot pounds for each 1,000 pounds of steam while pumping at the rate of 14 million gallons in 24 hours against a head of 150 feet, with a steam pressure not to exceed 85 pounds per square inch. The engine was first put into operation in July, 1897, and an expert test made in October of the same year developed a duty of 126,600,000 foot pounds per 1,000 pounds of steam.

On October 26, 1897, a contract for an engine of the same type and like capacity was let to the Holly Mfg. Co. to be installed in the 68th street station in place of the old Cope & Maxwell pumps, which were disposed of to the contractor. The engine with its boilers and appurtenances were exact duplicates of the new Lake View engine, and it was put into operation in 1898.

On October 26, 1897, a contract was made with the Lake Erie Engineering Works of Buffalo, N. Y., providing for the installation in the 14th street station of a 30 million gallon vertical, triple-expansion, direct-acting, crank and fly wheel engine. The engine has three steam cylinders 34, 60 and 94 inches in diameter, in which the pistons are double acting, and three single acting water plungers 60 inches in diameter, all having a stroke of 60 inches. The steam cylinders are placed side by side on "A" frames vertically over the pumps, and each piston is connected rigidly to its corresponding water plunger. Between the steam cylinders and the pumps is the crank shaft, carrying two fly wheels. The cranks are 120 degrees apart and each is connected by a connecting rod to its corresponding cross head. Each piston is connected to its cross head by two piston rods, and the connection from cross head to water plunger below is made by four rods, two on each side of the crank shaft. The suction pipe enters the pump chambers under the high pressure cylinder. All steam and exhaust valves are of the Corliss type and are placed in the cylinder heads. The cut-off of the high-pressure cylinder is controlled by a governor, while the cut-offs of the intermediate and low pressure cylinders are adjustable by hand. The cylinders are all steam jacketed, with reheaters placed between them. The feed pump, air pump, etc., are driven from an arm on the low pressure plunger cross head. Steam is supplied from two Babcock & Wilcox water tube boilers equipped with Roney mechanical stokers. The engine was required to develop a duty of not less than 135 million pounds of water raised one foot high for each 1,000 pounds of steam, and to pump not less than 30 million gallons of water per 24 hours against a head of 150 feet, with steam pressure at the throttle not to exceed 150 pounds per square inch. The engine was put into commission October, 1898, and an expert test made March, 1899, showed a duty of 152,952,000 feet pounds per 1,000 pounds steam.

In order to properly distribute with the least loss through frictional resistance the additional supply from the new stations, and also to provide necessary feeders in connection with the new engines installed in the 14th street and 68th street stations, it was necessary to construct an extensive system of distributing mains. This work was designed with a view of reaching directly, as far as possible, and indirectly by connecting with existing mains, all parts of the city, thus more nearly equalizing pressures and materially reducing friction. The main portion of this new system, constructed during 1898 and 1899, extends generally from Montrose boulevard on the north, connecting at that point with the large main running westward from the Lake View station to 67th street on the south, and following closely the line of Central Park avenue. At regular intervals connections are made with the old east and west mains. A new feeder system was also laid in the down town district, extending from the 14th street pumping station by way of 14th street, north on Michigan avenue to Adams street; in Adams street from Michigan to Wabash avenues, and on Harrison street from Michigan to Fifth avenues, connecting with the old 36-inch mains. An additional feeder was also laid westward from the 68th street station, extending to Chicago Lawn at 63d street and Central Park avenue. One result of this extension was to supply Chicago Lawn, a territory of about 4,000 inhabitants, with lake water. This district had previously obtained its water from cisterns and wells.

A system of 24 and 16 inch mains was laid in 1899 on North Ashland avenue and North Clark street, extending from the existing 36-inch main on Montrose boulevard to the north limits of the city.

In order to provide adequate service for that portion of the north side, north of Oak street and adjacent to the North Branch and Goose Island, a new feeder system was laid in this district during 1900. It extends from the old 24-inch Oak street main north on Larrabee street to Belden avenue, thence west on Belden avenue to and connecting with the 16-inch main on Halsted street. This system also includes a new 12-inch main on Garfield avenue from Cleveland avenue to Clark street. During 1899 over four miles of 12-inch main were laid from Avenue M and 107th street to Buffalo avenue and 133d street, to supply the town of Hegewisch.

The construction of these new distribution systems involved the laying of 55 miles of pipe, ranging from 36 to 12 inches in diameter, and an expenditure of over $1,000,000 for labor and material.

During the past three years 22 miles of 4-inch pipes, which were too small to supply the increased demand for water, have been taken up and replaced with larger pipe. These improvements to the water pipe system, in connection with the installation of the new pumping machinery, have resulted in effecting a satisfactory water pressure practically in all portions of the city excepting in the extreme southwestern portion.

In extreme weather that portion of the city west of Pullman and south of 107th street does not obtain a satisfactory supply of water. This district during the past few years has grown so rapidly in manufacturing industries, and consequently in population, that the 68th street station has been taxed to its limit, with the result that immediate steps must be taken to furnish adequate service to this district. The only positive relief will be obtained through the construction of another independent lake tunnel extending cross town to a new pumping station located somewhere in the vicinity of 103d and State streets.

During the period from 1897 to 1900 inclusive, the water pipe system was increased by the addition of 181 miles of pipe, 1,733 hydrants and 1,955 valves, the total number of miles of pipe in service at the close of 1900 being 1,872, with 19,108 hydrants and 14,862 stop valves.

As before stated, the water pumped at the Norwood Park station is obtained from an artesian well. On account of the gradual lowering of the normal level of the water in this well, it was decided to install the air lift method. For this purpose an air compressor and a new boiler were installed during 1897. In order to provide for the increasing demands of this district, a new well 1,800 feet deep, 15 inches in diameter at the top, decreasing to 6 inches at the extreme depth, is being sunk. A double-acting deep well pump will be installed, and the well is guaranteed to furnish 350,000 gallons per 24 hours.

During 1900 a horizontal compound condensing pumping engine, built by the Laidlaw-Dunn-Gordon Company, was installed in the Washington Heights station. It has a capacity of 1,500,000 gallons, and replaced the small Smith-Vaile engine.

The old wooden tank being in an advanced stage of decay, a contract was recently entered into with the Chicago Bridge & Iron Company for the erection on the grounds of the station of a steel tank of 188,000 gallons capacity, to be set on latticed steel posts 100 feet high.

For many years the annual reports of the City Engineers dwelt on the urgent necessity of replacing the four beam engines in the Chicago avenue station with modern machinery. The boilers supplying steam to the engines had greatly deteriorated, requiring continual repairs, involving large annual expenditures. The plans, as recommended by the City Engineer in 1898, called for the installation of three vertical triple expansion engines, each of a 25 million gallon daily capacity, to take the place of the four beam engines, steam to be supplied from six 250 horse power horizontal return tubular boilers, four to be sufficient to furnish steam to the three proposed engines. This would involve the construction of three new suction wells, and the rearrangement and simplification of the existing tunnels leading from the shafts in the rear of the station. The plans for the new plant also included coal conveyors, necessary hoppers, bins, and the reconstruction of the coal sheds, including an addition to the existing boiler rooms. The estimated cost was $350,000. Subsequently, as a result of the placing of additional machinery in the Lake View, 68th street and 14th street stations, and the opening of the new stations, the demand on the Chicago avenue station was lessened, and at the present time the pumpage does not exceed 50 million gallons daily. It was further recommended, therefore, that the two Gaskill engines be transferred to and placed in the Lake View station. The pumpage at this station is at present about 35 million gallons daily, the maximum capacity being 44 million gallons. The addition of these two engines would increase the pumpage to a total of 68 million gallons, sufficient to provide the rapidly growing territory depending on this station with an ample supply for some years to come.

Assuming that the Rogers Park station would shortly be acquired by the city, the Lake View station would be able to supply this district and the Rogers Park plant be abandoned. With a velocity of 3⅔ feet per second, the present Lake View tunnel is able to supply the maximum capacity required by this proposed increase in the pumping machinery. It might be added that with this addition the present engines would have to be lowered about five or six feet iin order to keep the maximum lift within a reasonable limit.

The four beam engines at the Chicago avenue station in running order at this date are expensive to operate and require constant repairs in order to keep them in continuous service. About 1,000 horse power is developed daily, requiring nearly five pounds of coal per horse power per hour. With the old boilers about 22,000 tons of coal are required to operate the station at a total annual cost of about $75,000, fifty per cent of the coal used being anthracite. Late duty trials of triple expansion condensing engines show that with the best quality bituminous coal they can be operated with a coal consumption of 1½ pounds per horse power hour. The triple expansion engines at the 14th street and Harrison street stations are operated in every day practice with a consumption of 2½ pounds of coal per horse power hour. On the basis of 1,000 horse power developed by the pumpage of 50 million gallons daily with this type of engine against a head of 110 feet, and using boilers equipped with smoke preventing devices, 31 tons of bituminous coal would be required daily at an average daily cost of about $100, or a saving in fuel over present conditions of about $40,000 annually. The removal of the Gaskill engine would effect an additional annual saving in salaries at this station of about $20,000.

In accordance with the recommendation of the City Engineer, the annual budget for 1899 included an appropriation of $350,000 for proposed improvements of the Chicago avenue station, of which $50,000 was to be expended during that year. Detail plans and specifications were at once prepared providing for a new boiler plant. The requirements called in general for six horizontal internally fired return tubular boilers, each with a capacity of 225 horse power, each horse power to mean 34½ pounds of water evaporated per hour from feed water of a temperature of 212 degrees into steam at atmospheric pressure, and to be properly proportioned for a maximum steam pressure of 200 pounds per square inch. The boiler plant was specified to include necessary feed pumps, purifiers, heaters, feed water measuring tanks and necessary steam piping, all in duplicate. A complete coal conveying machinery plant was also called for. A contract was let July

18, 1899, to John Mohr & Sons, of Chicago, for six boilers of the capacity specified, each to be 10 feet 6 inches in diameter, 15 feet 3 inches long, and each to have two Morrison corrugated furnace flues 48 inches in diameter. The efficiency guaranteed was the evaporation from and at 212 degrees of 12 pounds of water per pound of combustible when using Pocahontas coal. The stokers accepted are of the Hawley type and guaranteed to prevent 90 per cent of the smoke. The detailed plans of the contractor as finally accepted include coal bunkers with a total capacity of 500 tons, having down spouts leading to each of the Hawley furnaces, and equipped with Clark automatic coal weighing machines. Necessary conveying and coal crushing machinery is also included. Three purifiers of the Baragwanath horizontal type are supplied. Two single Deane feed pumps, 12 x 7 x 12 inches, of the pressure pump pattern, each of ample capacity to feed all three batteries, are also being installed. The installation of these new boilers required an addition to the present rooms 36 x 47 feet, the reconstruction of the roofs to give proper head room for the coal conveying machinery, and certain other changes by which the new batteries are all housed in one room. At this time two batteries of boilers are in place, and within the next six months the entire boiler plant, including the coal conveying machinery, will be in operation, resulting in a large decrease in the cost of fuel.

Notwithstanding the importance of at once beginning the installation of modern machinery to take the place of the antiquated engines now in use at the Chicago avenue station, the City Council has as yet failed to make specific appropriation for this work.

An important improvement, for which plans are on file, and which has been recommended annually for the past three years, but for which no Council authority has yet been given, is the extension of the three tunnels, terminating at present at the old two-mile crib in one tunnel, to the intake shaft already constructed in the Carter H. Harrison crib. The old crib, built in 1865, is not only rapidly deteriorating, but on account of the position of the ports requires an annual expenditure of $15,000 for labor and tug service, the greater portion of which is necessary to fight the ice that every winter threatens to endanger the water supply obtained from this crib. The estimated cost of this extension, including the removal of the crib, is $200,000.

No mention has yet been made in this paper of the numerous tunnels built to accommodate the water mains under the Chicago River and its branches. There are 17 in all, located at the following points, all of which have been built or are maintained by the City of Chicago, with the exception of La Salle street:

Adams street and river.

Archer avenue and river.

Ashland avenue and west arm of South Fork.

Chicago avenue and river.
Clybourn place and river.
Division street and canal.
Division street and river.
Eighteenth street and South Branch.
Harrison street and river.
Kedzie avenue, W. B. South Fork, Sanitary Canal and Illinois and Michigan Canal.
La Salle street and river.
Ninety-fifth street and Calumet river.
N. Western avenue and river.
Rush street and river.
State street and river (24-inch main abandoned).
Thirty-fifth street and river.
Throop street and river.

During 1900 there was pumped a daily average of 322,599,630 gallons, which, based on the school census of 2,007,695 inhabitants, represents a daily average of 161 gallons per capita. The number of miles of water mains in service at this time is 1,872; the number of meters is 6,396, and the number of valves is 14,862. Lake water is taken from 5 cribs and through 37 miles of tunnels. There are 10 stations operated by the city, the total capacity of which is 528,375,000 gallons daily. The number of engines available is 36, steam to which is supplied from 80 boilers. An average of 350 men is employed in the operation, maintenance and repairs of the various stations, involving a daily outlay for salaries of over $800. An average of 260 tons of coal is consumed daily, calling for an annual expenditure for fuel of $350,000.

The total cost of the water works plant to date is placed at $35,000,000. The water receipts for 1900 were $3,401,999.31.

DISCUSSION.

JOHN ERICSON, M. W. S. E., City Engineer, Chicago.
June 5, 1901.

It would seem that with a pumping system the nominal capacity of which is 529½ million gallons per day of 24 hours, and the present daily pumpage of about 360 million gallons, making an average daily per capita supply of about 177 gallons, there would be no need for any further extensions of the system (except distributing and service pipes) for some years to come.

Notwithstanding the many improvements that have lately been made and that have been so fully described by Mr. Spengler, I have received complaints from West Pullman and Washington Heights districts about a shortage in the water supply. I immediately started an investigation with a view of ascertaining the cause for the apparent shortage. Referring to that part of the city lying south of 87th street, and where the situation now demands attention, I find that the population, as per the school census, has increased from 47,693 in 1892 to 70,636 in 1900, while the consumption per capita for the whole city has increased from 134 gallons in 1892 to 161 gallons in 1900, in a manner as shown by the accompanying diagram. (Plate I.)

When it is further taken into consideration that towns like Hegewisch, West Pullman and Washington Heights are located from 9 to 11 miles from the pumping station, necessitating the forcing of the water these long distances, thus causing great loss in head through friction and loss of water through leakage, it will become at once apparent that what may have been sufficient as regards the water supply a few years ago cannot be so now without some further improvements. (Plate II.)

In order to meet the present emergency I propose the following:

First, that in order to derive as much benefit as possible from the Central Park avenue pumping station in this district, a 24 inch main be laid in 51st street between California and Western avenues, connecting with the 24 inch mains in these streets.

Second, that the 16 inch main in Ashland avenue be extended south from 75th street to the Washington Heights pumping station.

Third, that an additional 16 inch main be laid in 95th street from State street west to Eggleston avenue, then south in Eggleston avenue to 103rd street, then west in 103rd street to S. Halsted street.

Fourth, that an additional main 16 inches in diameter be laid in 119th street from State street to Centre avenue.

Fifth, that an additional 16 inch main be laid in Commercial avenue from 98th street to 114th street.

These improvements, however, will afford only temporary relief, and it becomes apparent at once, when the rate of increase in population is considered, that a more heroic treatment must be resorted to in order to bring permanent relief to this rapidly developing section of the city.

The most feasible scheme that suggests itself to me is the construction of a new pumping station somewhere in the neighborhood of 103rd street and the Illinois Central Railroad, to be fed by a tunnel terminating at or near the 68th street crib. The mains suggested to give temporary relief may serve as feeders from this plant when installed.

The ultimate maximum capacity of the 68th street station after a new pump shall have been installed will be 95 million gallons per day.

Assuming this station to supply all that district lying south of 39th street, we have an area of 96.6 square miles depending entirely on this one station; while the northern portion of the city, comprising 94 square miles (less than one-half of the total area), is equipped with eight pumping stations with a present available capacity of 446 million gallons per day, and which can be largely increased by additional pumping machinery, provision for which has already been made at several stations as regards room, tunnel capacity, etc.

Since the completion of the Central Park avenue pumping station, it may be claimed that the southern portion of the city derives some benefit from the 24 inch main in California avenue supplied by this station. Deducting for this the district lying between 39th and 47th streets, amounting to 7.6 square miles, we still have an area of 89 square miles entirely dependent on the 68th street pumping station. It may be here stated that observations of the water pressures lately taken show the low pressure line to be between 43rd and 47th streets.

The population of the city (school census, 1900) was 2,007,695, of which 348,467 is south of 47th street, and the balance of 1,659,228 being north of 47th street. If this latter amount be equally distributed over the entire north territory, the population would amount to 16,300 inhabitants per square mile. On this basis a supply of 150 gallons per capita per day would call for 1,445,000 gallons per square mile, an amount the 68th street pumping station could not deliver to the south side. As a matter of fact, however, the population is not equally distributed; but, for the purpose of intelligently estimating the ultimate needs of the southern portion of the city, it would be well to consider each square mile of territory capable of sustaining 16,300 inhabitants, this being about one-fifth of the population per square mile of the older portions of the city. The district lying between Division street and 12th street and Paulina street and the river has a population of 83,800 per square mile. The amount of water necessary to supply this district at some future date would then be 16,300x89x150, equal to 128,605,000 gallons per day. Of course, provision need not be made at once for all of this increase, but the tunnel and the pumping station should certainly be of sufficient capacity to ultimately take care of this whole district, with whatever assistance can be obtained from the 68th street station.

In order to provide for a probable territorial expansion on the west, which has not yet been taken into consideration, the pumping station should be located as near to the present western boundary as practical without making the tunnel unnecessarily long.

The building should be designed to provide for additional pumps in the future, and the tunnel should be of sufficient size and capacity to meet all future requirements of this section.

When considering the great quantity of water used per capita, my thoughts were turned in another direction, and it seemed to me well to take up a new question relating to the system for study and investigation, viz., the relative proportion of waste and legitimate use of the water pumped. That a large proportion of the water pumped at great expense is wasted has long been suspected, but, so far as I know, there has never before been an attempt to ascertain even the approximate amount, and therefore no systematic attempt to prevent such waste.

Before a remedy can be intelligently applied, a diagnosis of the causes of a trouble or disorder should be ascertained. In order to ascertain approximately the relative amounts of water used and wasted, I have prepared a diagram showing the hourly pumpage per capita for a period of ten days, commencing at midnight between February 28 and March 1, and ending at 12 o'clock midnight on March 10, 1901, embracing a period when the thermometer registered above and below the freezing point, and when there should be no extraordinary waste on account of too cold or too hot weather. In this I have followed closely the method adopted by Mr. John R. Freeman, C. E., New York City, in his report to Comptroller Coler of New York. The temperature of the external air for each hour, as recorded by the United States Weather Bureau of Chicago, has also been platted, and the variations are indicated by a broken line on the plat. (Plate III.)

While no definite conclusions should be drawn from any one set of observations, it is, however, significant and interesting to know from the accompanying diagram that whenever the temperature went below the freezing point, both the night and day pumpage increased, tending to show that even at a time when the winter was nearly over, the average temperature being rather above the freezing point, if a few days of freezing weather occurs the waste immediately increases to a considerable extent.

It will be further noticed that the geatest pumpage occurs between the hours of about 8 A. M. and 5 P. M., and the least between the hours of 1 A. M. and 5 A. M., also that the pumpage is considerably less on Sundays than on other days. It is probable that very little water is used between the hours of 1 A. M. and 5 A. M., the tanks no doubt being nearly all filled at the hour of 1 A. M.

Special inquiry made at my request by Mr. Lanagan, Mechanical Engineer, Bureau of Engineers, Chicago, tends to show that no tanks are being filled after 1 o'clock A. M., and that but little water is used by manufacturers' establishments during these hours.

Careful investigations made by Mr. Freeman and others, in cities where nearly all water used is metered, show a consumption between the hours of 2 A. M. and 4 A. M. of from 9. 5 to 12 gallons per capita per 24 hours. This includes the waste of water after passing the meters, and Mr. Freeman comes to the conclusion that the actual necessary use of water between these early morning hours is possibly only at the rate of 4 gallons per capita per 24 hours.

In order not to overestimate the waste, and owing to the many large manufacturing establishments in this city, I have assumed the consumption of water during the quietest hours of the night at the rate of 23 gallons per capita per 24 hours, which I consider an exceedingly liberal estimate.

By referring to the diagram (Plate III), there is shown an upper portion, bounded by an irregular upper line and marked "Water for necessary use," which is about 15¼ per cent of the total pumpage. Next below is a narrow belt, marked "Doubtful whether used or wasted," and taken as 8½ per cent of the total pumpage. Lastly, at the lower part of the diagram is shown a solid portion, marked "Water probably wasted," and amounting to 76¼ per cent of the total pumpage. It is to be noted that this diagram represents the pumpage, consumption and useless waste at a time of year when there should be comparatively little waste on account of cold weather, and none on account of hot weather, and no sprinkling required; and that out of a total pumpage for ten days, 76¼ per cent is surely wasted, or if the doubtful portion of 8½ per cent be added, the waste amounts to 84¾ per cent of the total pumpage.

As the cost of fuel alone for pumpage in a year at present amounts to over $350,000.00, the cost of the fuel consumed to pump the water that is wasted must necessarily represent a considerable sum of money. It is, therefore, of considerable importance to study and investigate the causes for this enormous waste, and to apply remedies as far as it is possible and practicable to do so.

The waste may be ascribed to the following various causes, no attempt being made to mention them in the order of their importance:

1st. Defective joints and pipes in 1900 miles of mains. The mains laid in annexed territories previous to annexation, mostly by contract under poor inspection, and mains laid under special assessment previous to 1898, when there was imperfect or no inspection, unquestionably cause great leakage. Electrolysis and old deteriorated pipes are also causes for considerable waste.

2nd. Defective, leaky and abandoned service pipes between the mains and the curb walls.

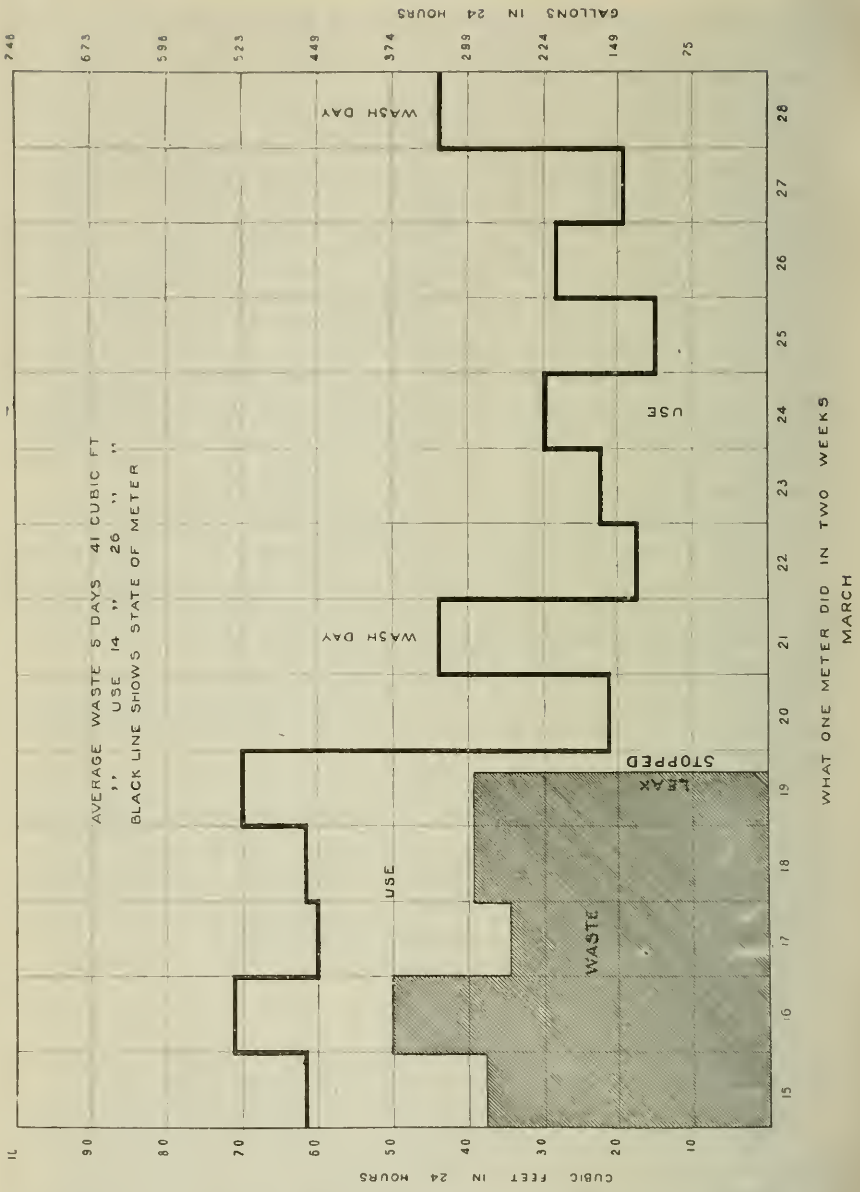
3rd. Defective house plumbing.

4th. Leaving faucets unnecessarily open in winter to prevent freezing, and in summer to keep water and other matter cool.

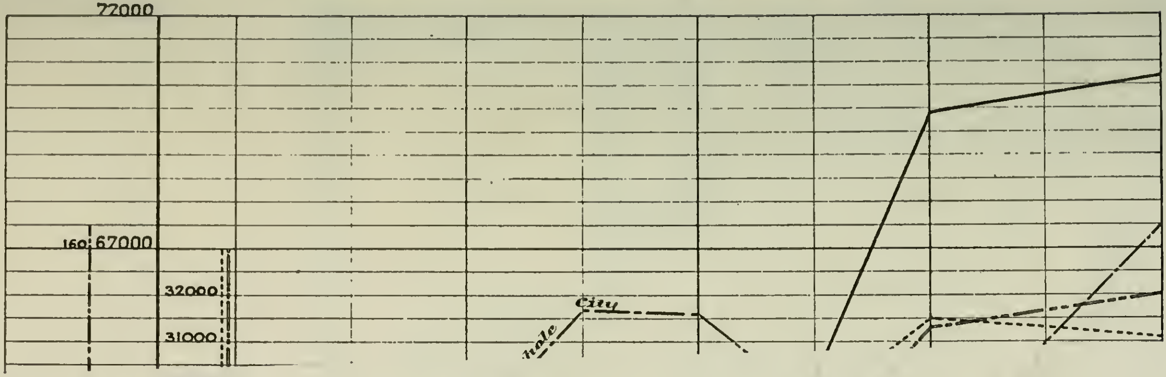
5th. Unnecessary and willful waste, overflowing tanks, etc., etc.

While the waste of water cannot be entirely prevented, the amount can, however, be materially reduced. The advisability of placing meters on all service connections deserves to be seriously considered. I am of the opinion that at least 50 per cent of the waste can be prevented by such a step.

As an illustration to show that this is not an exaggeration, it is interesting to note the experience of an engineer of Hartford, Conn., described in the *Water and Gas Review* for May, 1901. On the 14th day of March a water meter was put into the house of this



engineer. A series of readings was immediately commenced to ascertain the total water passing the meter, the waste, and the difference or actual use. To determine the amount of waste, readings were taken late at night, after all use had ceased, and early in the morning just before use had commenced. The results are graphically shown on the accompanying diagram. The and Daily water supply per capita.



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Vol. VI. No. 4.—PLATE I.
Ericson—Water Works System, Chicago.

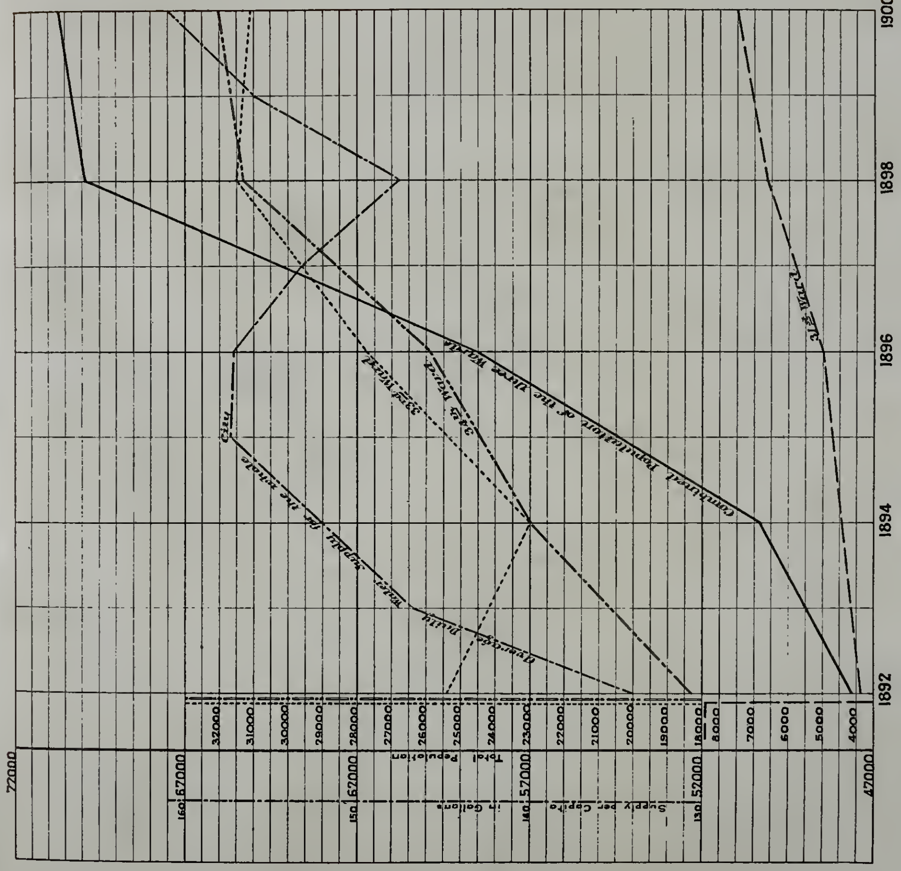
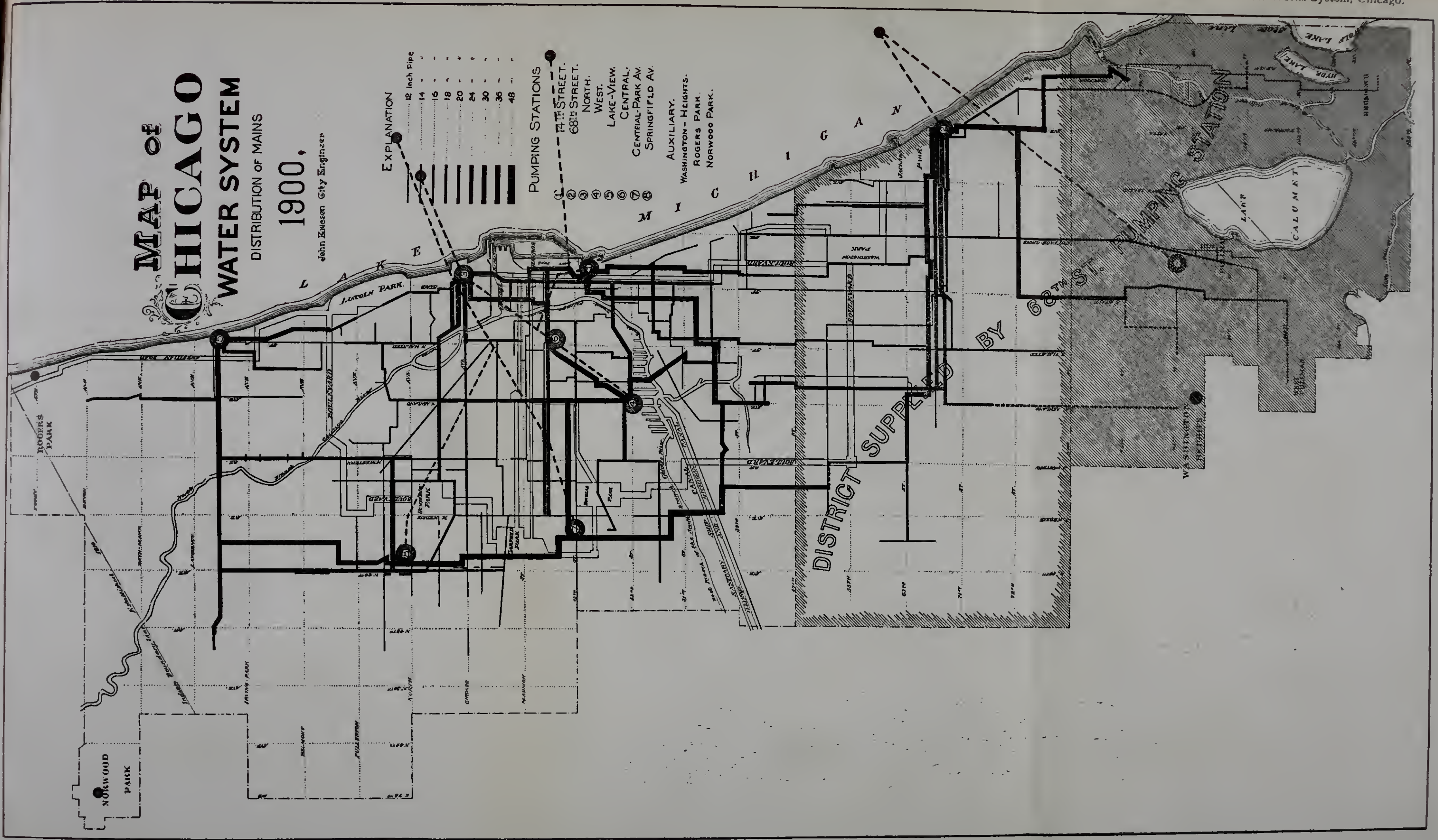


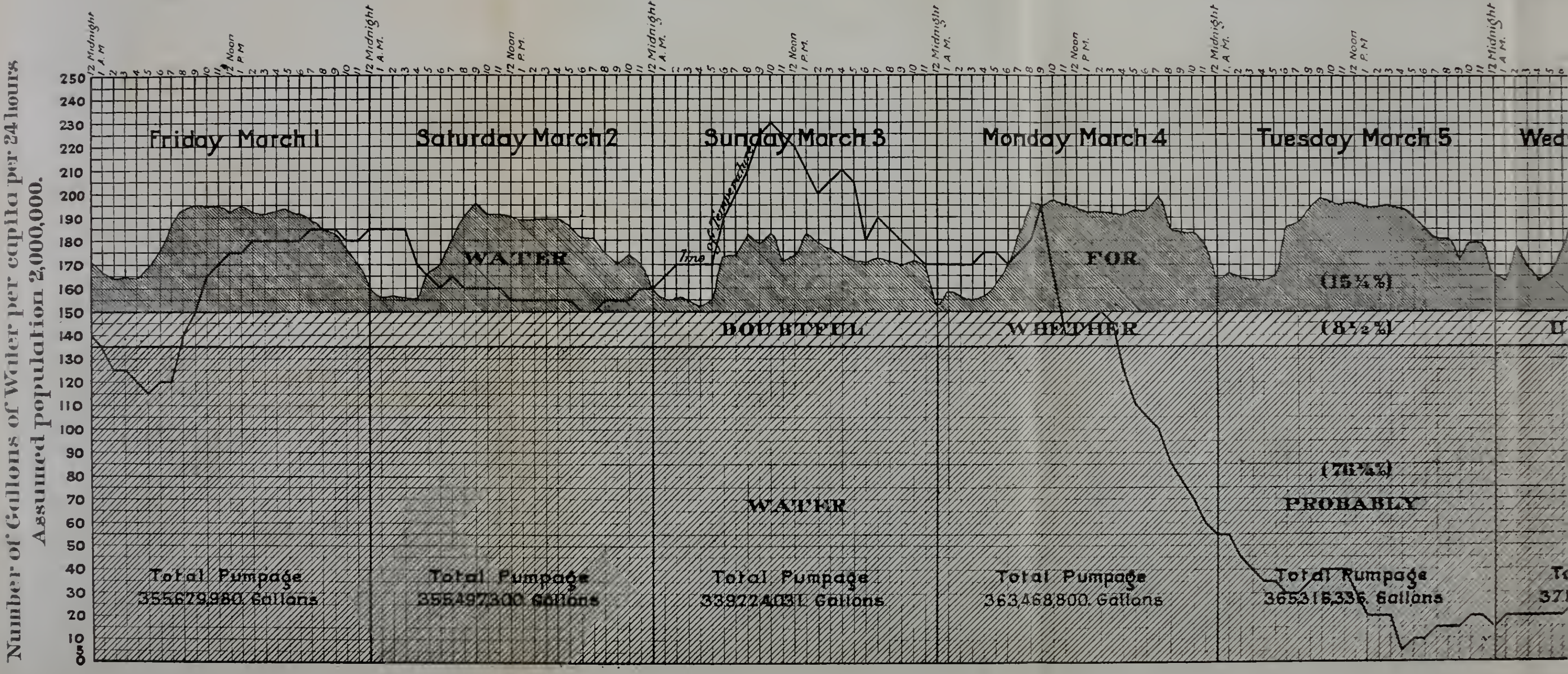
Diagram showing increase in Population, South of 87th Street; and Daily water supply per capita.


MAP of CHICAGO
WATER SYSTEM
DISTRIBUTION of MAINS
1900.
John Ericson City Engineer
EXPLANATION
12 Inch Pipe
14
16
18
20
24
30
36
48
PUMPING STATIONS
① 14TH STREET.
② 68TH STREET.
③ NORTH.
④ WEST.
⑤ LAKE-VIEW.
⑥ CENTRAL.
⑦ CENTRAL-PARK AV.
⑧ SPRINGFIELD AV.
AUXILIARY.
WASHINGTON-HEIGHTS.
ROGERS PARK.
NORWOOD PARK.
LAKE MICHIGAN
LINCOLN PARK
DISTRICT SUPPLIED BY 68TH ST. PUMPING STATION
ROGERS PARK
NORWOOD PARK
WASHINGTON HEIGHTS
LAKE CALUMET
HYDE LAKE
WOLF LAKE
Chicago River
SANITARY CANAL
WASHINGTON PARK
HUMBOLDT PARK
GARFIELD PARK
DOUGLAS PARK
BOULEVARD
WEST PULLMAN

DIAGRA

Showing approximately the relative Use and W

March 1 to March 10, in

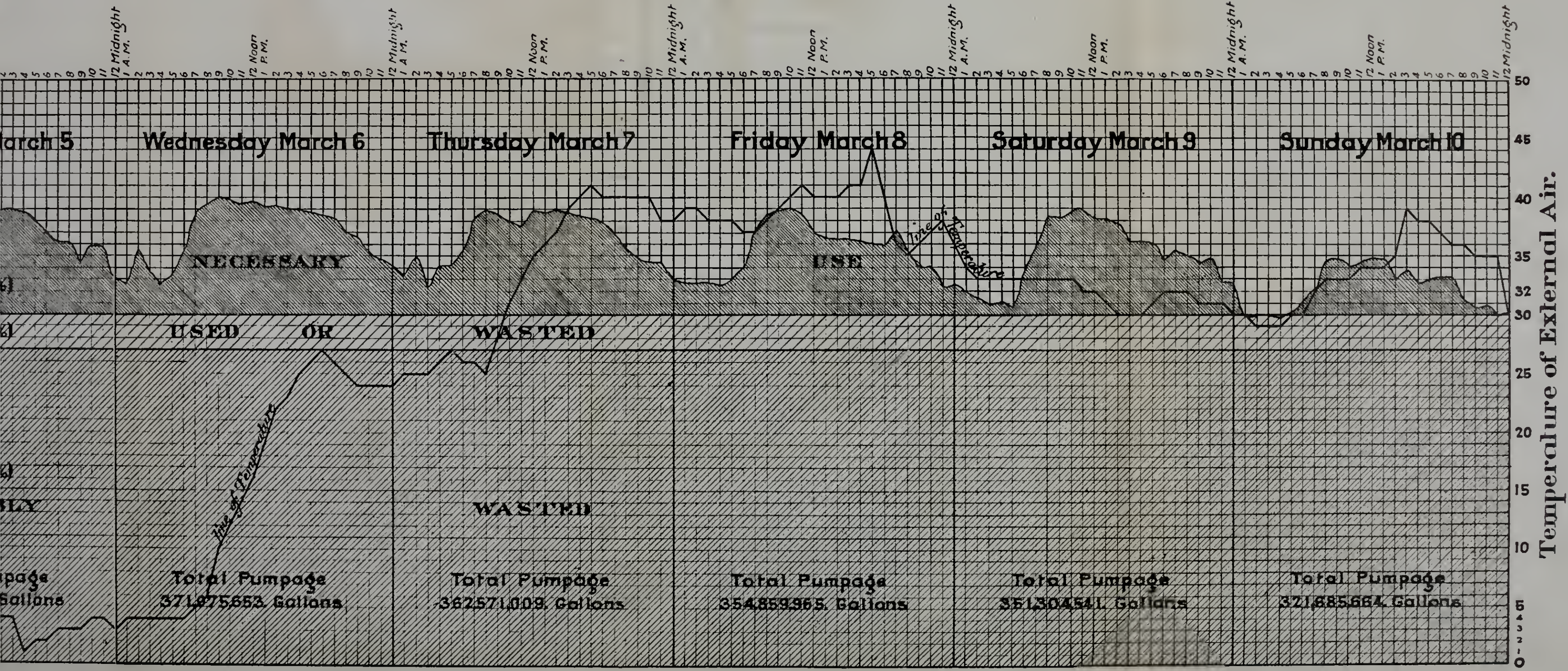


Western Society of Engineers.
Vol. VI, No. 4.—Plate III.
Ericson—Water Works System, Chicago.

DIAGRAM

se and Waste of Water pumped by the City of Chicago

March 10, inclusive. 1901.



STATISTICS SHOWING GROWTH OF THE WATER WORKS SYSTEM OF THE CITY OF CHICAGO FROM 1854 UNTIL 1900.

COMPILED BY J. H. SPENGLER, ASS'T. CITY ENGINEER, CHICAGO.

Year.	Population. (School Census)	Average daily pumpage in gallons.	Average daily pumpage per capita.	Capacity of Works.	Average head pumped against.	Number of taps in use.	Number of meters in use.	Number of hydrants in use	Number of stop-valves in use.	Mileage of water-pipe in city.	Revenue from metered water.	Revenue from unmetered water.	Total Revenues.	Revenue per million gallons pumped.	Total coal used, in tons.	Average cost of coal per ton.	Total average cost of pumping one million gallons one foot high.	Year.
1854	65,872	591,083	6.9	8,000,000	....	....	....	123	....	30.0	....	....	....	....	504	....	....	1854
1855	80,023	2,392,945	29.9	8,000,000	....	....	....	158	....	43.0	....	....	$ 58,105.00	$66.52	1,079	....	....	1855
1856	84,113	4,000,000	47.5	8,000,000	....	....	....	169	....	62.4	....	....	80,000.00	54.64	....	....	....	1856
1857	93,000	3,552,052	38.2	8,000,000	....	....	....	182	....	58.0	....	....	97,008.00	74.83	1,966	....	....	1857
1858	84,000	2,991,413	35.6	20,000,000	....	4,666	....	273	....	72.4	....	....	102,179.00	93.58	....	....	....	1858
1859	94,000	3,877,119	41.2	20,000,000	....	6,511	....	388	....	85.1	....	....	122,753.00	86.74	2,324	....	....	1859
1860	109,260	4,703,525	43.0	20,000,000	....	6,350	....	....	....	91.0	....	....	131,162.00	76.19	2,621	....	....	1860
1861	120,000	4,841,520	40.3	20,000,000	....	6,876	....	....	....	95.3	....	....	150,290.00	85.04	2,431	$3.84	.0864	1861
1862	137,030	6,074,739	44.3	20,000,000	....	7,450	65	....	....	104.9	....	....	150,920.00	68.06	2,970	3.53	.0855	1862
1863	150,000	6,400,298	42.6	20,000,000	....	8,412	99	548	298	117.9	....	....	192,246.00	82.29	3,130	6.63	.1236	1863
1864	161,288	6,913,259	42.8	20,000,000	....	9,855	133	606	332	127.3	....	....	224,902.00	88.88	3,149	9.94	.1849	1864
1865	178,492	7,610,459	42.6	20,000,000	....	11,406	147	762	402	141.2	....	....	253,114.00	91.11	3,450	9.21	.1525	1865
1866	200,418	8,681,536	43.3	20,000,000	....	13,634	179	790	454	156.5	....	....	302,017.00	95.31	3,680	8.51	.1403	1866
1867	225,000	11,562,273	51.3	20,000,000	....	16,498	253	919	457	179.4	....	....	338,929.00	80.31	5,316	7.30	.1186	1867
1868	252,054	14,724,999	58.4	38,000,000	....	20,915	400	1,070	501	208.6	....	....	420,686.00	78.06	5,584	7.60	.1245	1868
1869	279,329	18,033,278	66.7	38,000,000	....	28,308	530	1,294	623	239.9	....	....	476,968.00	70.13	8,737	6.93	.1171	1869
1870	306,605	21,766,260	70.9	38,000,000	....	35,318	656	1,552	1,076	272.4	....	....	639,180.00	67.86	9,311	7.49	.1131	1870
1871	337,000	23,464.877	69.6	38,000,000	....	38,110	341	1,667	1,392	287.7	....	....	445,834.00	52.06	10,267	8.09	.1203	1871
1872	367,396	27,536,819	74.9	38,000,000	....	42,511	618	1,799	1,537	310.8	....	....	544,465.00	54.02	13,925	7.18	.1164	1872
1873	381,402	32,117,312	84.2	74,000,000	....	47,995	836	2,254	1,794	351.4	....	....	708,804.00	60.46	15,120	8.58	.1225	1873
1874	395,408	38,090,952	96.3	74,000,000	....	51,563	1,174	2,607	2,123	386.4	....	....	705,928.00	50.77	16,958	8.27	.1168	1874
1875	401,534	39,844,556	99.2	74,000,000	....	55,293	1,313	2,835	2,416	410.0	....	....	635,998.00	45.74	12,318	7.92	.1030	1875
1876	407,661	41,931,481	102.8	74,000,000	....	67,130	1,446	2,901	2,590	416.4	....	....	771,940.38	50.30	16,805	7.15	.0846	1876
1877	422,196	52,183,892	123.6	104,000,000	....	59,369	1,623	3,002	2,701	424.6	....	....	908,509.00	47.67	17,303	5.38	.0611	1877
1878	436,731	53,600,789	122.7	104,000,000	....	61,384	1,888	3,130	2,836	429.9	....	....	944,190.00	48.26	13,028	4.39	.0514	1878
1879	464,123	66,322,441	121.3	104,000,000	....	63,510	2,067	3,228	2,992	441.3	....	....	922,001.00	44.85	18,557	4.12	.0534	1879
1880	491,516	67,384,376	116.7	104,000,000	....	67,949	2,113	3,361	3,105	455.4	....	....	865,618.35	41.21	16,363	4 37	.0537	1880
1881	526,104	63,922,700	121.5	104,000,000	....	73,627	2,163	3,553	3,531	472.3	....	....	936,922.07	40.11	16,756	5.51	.0636	1881
1882	560,693	66,166,969	118.0	104,000,000	....	78,840	2,310	3,872	3,720	497.2	....	....	1,049,576.90	43.50	17,169	4.58	.0643	1882
1883	595,339	73,265,592	123.0	104,000,000	....	85,496	2,503	4,144	3,861	518.6	....	....	1,142,868.00	42.73	20,203	4.28	.0646	1883
1884	629,985	80,017,990	127.0	134,000,000	....	92,133	2,685	4,616	4,022	543.3	....	....	1,204,338.00	41.12	20,286	5.04	.0639	1884
1885	666,901	91,650,190	137.4	134,000,000	....	98,688	2,897	4,943	4,196	565.1	....	....	1,339,038.00	40.00	27,719	4.39	.0543	1885
1886	703,817	97,789,706	138.9	134,000,000	....	106,771	3,085	5,350	4,432	596.0	....	....	1,374,837.00	38.52	29,442	4.60	.0586	1886
1887	753,234	101,937,842	135.3	134,000,000	....	115,578	3,273	5,889	4,736	638.2	....	....	1,490,000.00	40.04	29,645	4.54	.0595	1887
1888	802,651	104,315,624	129.9	158,000,000	....	125,667	3,122	6,378	5,099	677.1	....	....	1,557,116.00	40.78	30,174	4.60	.0621	1888
1889	1,005,660	110,895,707	110.2	158,000,000	....	133,284	3,287	10,456	7,444	729.8	....	....	1,621,750.00	40.07	30,617	4.07	.0527	1889
1890	1,208,669	152,372,288	126.0	260,000,000	....	155,096	3,924	11,836	8,595	1,205.0	....	....	2,109,508.00	37.93	46,190	3.48	.0623	1890
1891	1,323,339	174,114,254	131.5	260,000,000	110.0	182,382	4,131	13,411	9,739	1,346.7	$ 717,068.05	$1,647,395.04	2,364,463.09	37.21	55,293	4.02	.0517	1891
1892	1,438,010	194,086,000	135.0	357,500,000	99.8	203,954	4,326	14,099	10,384	1,402.3	795,292.72	1,943,141.38	2,738,434.10	38.55	69,023	3.99	.0562	1892
1893	1,502,868	236,434,176	157.3	357,500,000	112.9	242,208	4,654	14,894	11,014	1,473.7	1,000,582.70	1,948,966.17	2,949,548.87	34.18	80,050	4.32	.0552	1893
1894	1,567,727	238,521,280	152.1	357,500,000	111.6	258,092	4,878	15,771	11,597	1,546.7	1,012,395.56	2,146,097.38	3,158,492.94	36.27	82,139	4.13	.0582	1894
1895	1,592,183	251,839,816	158.1	357,500,000	109.9	272,758	5,120	16,466	12,073	1,612.4	1,004,203.48	2,314,280.37	3,318,483.85	36.20	89,033	3.78	.0530	1895
1896	1,616,635	254,208,509	157.3	357,500,000	109.6	276,240	6,106	17,375	12,907	1,691.3	1,039,283.43	2,187,276.30	3,226,559.73	34.68	89,538	3.63	.0460	1896
1897	1,734,111	265,462,539	163.0	366,000,000	106.5	286,179	5,396	17,833	13,366	1,730.3	937,654.61	2,240,052.22	3,177,706.83	32.79	91,582	3.79	.0476	1897
1898	1,851,688	273,055,816	147.4	412,000,000	106.5	292,386	5,837	18,311	14,025	1,801.4	1,087,858.31	2,401,532.66	3,489,390.87	35.02	92,452	3.42	.0495	1898
1899	1,929,641	300,614,394	155.7	412,000,000	111.6	299,901	6,185	18,825	14,484	1,846.9	1,086,948.44	2,115,883.33	3,202,831.77	29.19	98,932	3.36	.0405	1899
1900	2,007,695	322,599,630	160.6	528,375,000	110.9	308,945	6,396	19,108	14,862	1,872.0	1,144,644.36	2,105,837.49	3,250,481.85	27.57	94,990	3.41	.0479	1900

family consists of four adults and two children. Water is used freely. The plumbing in the house is characteristic of a well-to-do household. As the readings the first five days indicated considerable waste, a careful examination of the plumbing fixtures was made. One small stream was found running down the back of the bowl of one of the closets. A few of the faucets were found to drip at the rate of about one drop in one or two seconds. A plumber was called and stopped every visible leak. The leak in the closet was due to a worn valve, a very common defect. The effect of the repairing of the plumbing was very marked, as is shown by the diagram. The night readings of the meter now show that no water passed the meter at all. The readings after the 19th may all be considered legitimate use, and are about what may be expected with liberal usage.

When the great number of householders in Chicago is considered, it can be readily understood what an enormous amount of water is wasted on account of defective plumbing alone.

The revenue from the water system would be greatly increased by the adoption of meters, and it would be a step in the right direction to discover and thus to prevent waste in other parts of the system.

The amount of water used for domestic, manufacturing and other purposes in and around the buildings could thus be obtained, and by subtracting this amount from the total pumpage, some close approximation of the waste outside the buildings could be arrived at, there being ample facilities for estimating the amount of water used outside the buildings.

Plumbing would be kept in good repair, since every property owner, manufacturer and other consumer of water would undoubtedly find it to his interest to prevent waste of the water for which he would have to pay.

To ascertain the amount of waste through leaky joints in mains, abandoned and leaky service pipes, etc., outside the houses would require considerable time, expense and labor. The best method would probably be to divide the city into small districts and to meter all water entering into each district, and then substract the quantity registered by house meters, which first should have been placed. This could probably be done cheapest and in the shortest time by the so-called Pitot tube method. In this manner the importance of the leakage for each district could be obtained, and such steps taken to prevent same as would seem advisable and necessary.

Mr. Spengler I present herewith in the accompanying table (Plate IV) certain statistics that evolved a number of data from the year in which the water works system was first started, which show the average daily pumpage, the largest amount pumped in one day, population, average amount pumped per capita per day, revenues, etc, *Mr. Cooley* .Has any estimate ever been made of the cost of installing domestic meters?

Mr. Ericson I am at present working on this matter; I have some figures, but cannot give them until I verify several things. In some of the cities of the East the meters cost about $15.00 per meter, installed; that is, figuring on the ordinary size service pipe. The average life seems to be fifteen to twenty years; some last much longer. They cost in the East from $2.25 to $2.50 a year, including the interest on the money spent for the metre, placing the same, and putting the meter in repair four times a year.

Mr. Cooley How many domestic water metres are there in the city?

Mr. Ericson—The Water Department, which is at present separate from the Engineers' Department, reports about 300,000 service taps. Mr. Spengler's table shows 6396 meters in use.

Mr. Cooley— Have any meters ever been put on the regular main system?

Mr. Ericson There are none in Chicago that I know of.

Mr. Cooley—Do you consider it a good proposition?

Mr. Ericson—I do not know. I am looking into that matter and think that the method of obtaining amounts of water is so simple it would not pay to place any large meters on the mains.

The Deacon meter was tried in Boston for a long time and became so expensive they abandoned it.

Mr. Cooley—I know of the Ventura tube being used on the Deacon system with very good results, and continued in use twenty years on one public line without showing any evidence of deterioration. Would you consider the introduction of the Ventura meter advisable?

Mr. Ericson— I have it under consideration, but they come very expensive, and I do not know whether it is necessary to keep a constant record of water flowing through the mains, unless there are certain mains you wish to extend, and if you can obtain these ends in a cheaper and better manner, I should consider that that ought to be done. Of course, there may be cases where the Ventura meter would be a very good thing. I understand, however, that those small tubes I spoke about can be so arranged that they also record the flow of the water continuously.

Mr. Ashworth—I would like to ask Mr. Ericson what per cent of water is used by manufacturing places such as the stock-yards.

Mr. Ericson—I cannot answer that. Some idea could be obtained by examining the diagram. If you leave out Monday (washday) and take Tuesday, Wednesday, Thursday, Friday, Saturday, take an average of the pumpage on those days, and then subtract the pumpage on Sunday, you may get some idea of how much is used for manufacturing purposes, but I have not gone into the matter sufficiently to give any figures.

Mr. Tratman—What is the diameter and length of that proposed tunnel?

Mr. Ericson—We have not gone into the details yet, and it is simply a suggestion; but if the City Engineer is ordered to go ahead, that matter will be taken up carefully. From a preliminary figure, an 8-foot tunnel will be sufficient to supply the amount of water that they think will be needed for the future; it will be about six miles long.

Mr. Ashworth—I would like to ask in regard to the old tower system. If these old engines were abandoned, would it be necessary to have these towers?

Mr. Ericson—I do not consider that these towers are of any use at present; when the system gets to be so large as is our system here, the tower is of little use unless you have them scattered all over the city.

Mr. Ashworth—In the daytime, when the pressure is low, that is, when all the engines are running, in the outlying districts, such as Washington Heights and the western part of the city, the pressure drops considerably. At night the pressure rises, and it becomes necessary to shut some of the engines down. The question is, does any air accumulate in the pipes and how does the air escape?

Mr. Ericson—In the first place, if you take the 68th street station, there is no tower at all in that system, and I have never heard of any trouble on account of accumulation of air. It seems also, if that diagram speaks the truth, if we have a leakage of 76 to 80 per cent of water pumped, there will not be much difficulty in the air getting out.

Mr. Ashworth—Are the taps placed on the top or side of the main?

Mr. Ericson—They are generally placed on the top of the main.

Mr. Cooley—The argument has been made that pumping 30 or 40 gallons per day is a good thing for the sewers.

Mr. Ericson—I had that question put to me. I had quite a talk with Mr. McHarg, who has had an extensive experience with sewers, and knows a good deal about the sewer system of Chicago, and he claims by stopping the leakage it would not interfere with the flushing of the sewers at all. I do not know for certain yet what effect it would have on the flushing of the sewers, but that is the statement, and of course all those things would have to be carefully considered.

Mr. Chanute—I would like to ask whether any steps have been taken by the city authorities to investigate and diminish that waste of water, and if there is hope of such action being taken?

Mr. Ericson—As far as I am concerned I have submitted the matter to my superior, the Commissioner of Public Works, and the matter now rests with him. The City Engineer is powerless to d anything further until he receives authority from the Council and the Commissioner of Public Works to go ahead and do something to prevent this waste. The matter, I have no doubt, will be carefully considered and discussed by the Commissioner and the members of the City Council and the Mayor.

Mr. Ashworth—Are the parks supplied from the city mains?

Mr. Ericson—The west parks and south parks are supplied by the city mains. Lincoln Park has its own supply. I believe, however, a small amount is furnished Lincoln Park by the city, but the bulk of it is supplied by their own works.

Mr. Chanute—I would also ask what action has been taken by the public authorities toward increasing the supply in the Washington Heights district?

Mr. Ericson—I discussed the matter not later than to-day with the Commissioner of Public Works, and he is interested, very much so, in this question, and sees the necessity of it, and told me he would take it up immediately with the Mayor and see what can be done to carry out the improvements that I had recommended.

Mr. Chanute—I would say, in connection with that, that I am connected with the Chicago Tie Preserving Company, and that we have been short of water for some time all through this season. We were especially short to-day (June 5), and were glad to see this rain, hoping that the people who had been watering their gardens would cease and give us enough to run with. I can fully corroborate the statement made by Mr. Ericson that that portion of the city is suffering for an adequate supply of water.

Mr. Ericson—I believe that this is a question that should be taken up by the authorities at once. I have laid the whole matter before my superiors, and believe that it will be taken up and steps taken at once to construct a new pumping station and terminal. After authority is given to go ahead and prepare such plans, it will take considerable time for us to prepare such plans, make borings, etc., and after the contracts have been let, we know from experience it takes considerable time to complete such a system. Now, suppose it takes three years altogether, or two years even, the probability is that that district will have a population at that time of over 100,000 people, and unless steps are at once taken to carry out a project of this kind, I believe that we will simply have a repetition of the conditions that are appearing right along in other parts of the city. The city has never been able to keep up with the demands for water. We thought when we completed our large system up north there would be no more trouble for a while; but it was hardly completed before a cry came up from another part of the city, and we had to start right in again.

E. E. Russell Tratman—As a matter of record, I would mention that a long and illustrated article on the Chicago water supply system, and particularly of the intake tunnels, cribs and pumping stations, was published in Engineering News of Oct. 18 and Nov. 8, 1900. That article also gave a record of the various engineers connected with the water supply, and it is interesting to note that in the early days of the city three such eminent engineers as William J. MacAlpine, E. S. Chesbrough and John B. Jervis were connected with the designing and carrying out of the water supply system.

The following tables give in condensed form the capacity and other characteristics of the intake tunnels and the pumping plants, as corrected up to summer of 1900:

WATER SUPPLY TUNNELS.

	Diameter feet.	Length feet.	Cost.	Capacity gallons per 24 hours.
Lake View	6	9,999	$ 701,792	45,000,000
Chicago Ave	5	10,567	464,866	
	7	10,560	415,709	170,000,000
	7	10,908	299,897	
12th St. or Four Mile	8	9,139	1,104,744	95,000,000
	6	25,200		
Hyde Park or 68th St.	7	12,353	741,371	105,000,000
	5	8,132		
	6	5,026		
Northeast	10	14,108	610,560	200,000,000
Total. . . . .(21.97 miles)		115,992	$4,338,939	615,000,000

PUMPING STATIONS,

Pumping Station.	Present No. of engines.	Pumping capacity, gallons per 24 hours.	
		Present equipment, gallons.	Full equipment, gallons
1. Lake View	4	45,000,000	64,000,000
2. North Side	6	99,000,000	99,000,000
3. Central	2	36,000,000	36,000,000
4. 14th St.	4	84,000,000	84,000,000
5. West Side	4	60,000,000	60,000,000
6. Hyde Park	6	80,000,000	80,000,000
7. Central Park Ave	3	60,000,000	80,000,000
8. Springfield Ave	3	60,000,000	80,000,000
9. Washington Heights	2	1,400,000	2,500,000
10. Norwood Park	1	250,000	250,000
11. Rogers Park	2	3,000,000	3,000,000
Total	37	528,650,000	588,750,000

CXXIV.

THE CHICAGO RIVER.

By Thos. T. Johnston, M. W. S. E.

The further improvement of the Chicago River is a subject having many sides to it, and two sides in particular, namely: Navigation and Sanitary interests. There are, besides, to be considered, the suitability for commerce, the rights and interests of riparian owners and other minor things.

The limited discussion of the subject at the annual meeting of the Society was unfortunately a one-sided affair, the views expressed at that time coming exclusively from gentlemen leaning toward what may lead to an early and large expenditure of money, and a radical enlargement of the river in width and depth, or the equivalent. One or two of the speeches made were even partisan in their nature.

The writer, having evolved those plans for river improvement in accordance with which the Sanitary District has hitherto worked, and having been for many years and, until recently, identified in a responsible way with the work of the Sanitary District, makes bold to discuss the subject with a view to a broader presentation than we enjoyed at our anual meeting.

Sanitary Interests.

As far back as 1886 the writer was assigned to the study of the catchment basin of the Chicago River, which is shown upon the map, and has followed it quite closely since. While all of its parts are important it is desired to draw particular attention to that part which is drained by the North Branch. There is no question but that the flood discharge from this stream exceeds 200,000 cu. ft. per min., and sometimes reaching as much as 250,000 c. f. m. Unless this water finds a passage through the South Branch of the river to the drainage canal, it must of necessity go to Lake Michigan. The flood discharge from the South Branch basin exceeds 300,000 c. f. m., and that of the main river exceeds 500,000 c. f. m. The above distribution of flow had substantial existence in December 1896. When floods of this kind recur, a large part of the flow from the North Branch will go into Lake Michigan and affect the water supply under the existing conditions of the works of the Sanitary District in the Chicago river. To keep all this flow water, together with floods from south and west forks, from Lake Michigan, the flow in the main drainage canal would be substantially 600,000 c. f. m., and the Chicago River—the South Branch—must have its capacity made equal to taking the floods tributary to it as well as those of the North Branch. As the territory tributary to the North Branch becomes changed from rural to urban character, its floods will become more voluminous and the channels caring for them will have to be larger.

Confining ourselves still to the North Branch, it will be noticed that the city has under construction a large conduit from Lake Michigan to the North Branch at Lawrence avenue. It is to intercept the north shore sewers, and, in flood times, deliver 45,000 c. f. m. into the North Branch, increasing its floods to a volume of 250,000 to 300,000 c. f. m. It is also intended that in dry weather this conduit will deliver 45,000 c. f. m. to the North Branch to help dilute its filthy waters, thus establishing a low water flow of that volume plus the sewage, a combined volume of about 55,000 c. f. m. If the Fullerton avenue conduit be kept in commission, with its 12,000 c. f. m., then the dry weather flow will be 67,000 c. f. m. The contingency of the Evanston district, with its 20,000 people, being added to this basin, is to be considered also.

It appears, from the experience with the Drainage Canal (and the writer has personally observed its effect quite continuously at the water power plant he is building in Joliet), that 20,000 c. f. m., the legal requirement for each 100,000 people, is none too great a dilution, especially in warm weather. This will apply to the North Branch as well as elsewhere, whence it may be concluded that the dry weather flow from the North Branch should be made at least 150,000 c. f. m. at the present time, and be augmented as the region grows in population, if the North Branch is ever to be reduced to a sanitary condition.

The Chicago Drainage and Water Supply Commission of 1886 and 1887, from which the Sanitary District was evolved, and the only technical body that ever made a comprehensive study of the sanitary features of the Chicago region, contemplated that the North Branch should be fed with pure water from Lake Michigan to an amount in excess of 200,000 c. f. m.

It appears, then, that in the sanitary development of the Chicago River a condition of flow from the North Branch must be faced, as follows: Dry weather flow, 10,000, 55,000, 67,000, 150,000 or in excess of 200,000 c. f. m., according to the sanitary condition to be maintained; also, a wet weather flow reaching at times of considerable flood a volume between 250,000 and 300,000 c. f. m.

If it be simply a question of protecting the water supply, then arrangements must be made to prevent any flow into Lake Michigan, in objectionable quantity, which means that the South Branch must have the capacity to carry all the water that does not go into Lake Michigan. This might be accomplished if the flow into the South Branch of 150,000 c. f. m. be assured at all times, since the occurrence of floods of larger volume do not occur every year, and last but a short time when they do come in excess of that volume. Such a provision does not take into account increase of flood volume in future, as the region becomes occupied. The ideal will be, of course, to prevent any flow into Lake Michigan which would involve the assurance of a flow of 300,000 c. f. m. into the South Branch at all times. This was the view taken when the plans of Sanitary District before mentioned were evolved, and was one of the determining factors limiting the scope of the work. This was in accord with the policy of the Drainage and Water Supply Commission of 1886 and 1887, and, the writer believes, was proper.

If it be a question of maintaining the North Branch in a sanitary condition, which must sometime be done, then the flow from it will be at least 150,000 c. f. m. continuously now, and more as time goes on. A continuous flow of 200,000 c. f. m. or more, as contemplated in 1886 and 1887, would not be too much to provide for. The oscillations of Lake Michigan are such that there is a tendency at one time toward flow into the rivers and at other times a flow outward. In consequence of this, even when there is, on the average, an inflow, as was the case when the Bridgeport pumps were relied upon to create an inflow to the extent of 25,000 c. f. m. or more, there was, nevertheless, a material outflow. The advent of the drainage canal, with its flow of from 200,000 to 350,000 c. f. m., has changed the outflow, though on several occasions the writer has observed a very material flow of filthy water into the lake in wet weather. It follows, therefore, that if there be a continuous flow of 150,000 or 200,000 or 250,000 c. f. m, from the North Branch, then there should be added to this something like an average of 50,000 c. f. m. from Lake Michigan, and there should be assured a flow of 200,000, 250,000 or 300,000 into the South Branch. This, and some other considerations to be developed further on, again accentuate the propriety of an assurance of a flow of 300,000 c. f. m. into the South Branch.

The conditions pertaining to the South Branch basin may now be examined. It embraces all that area tributary to the South Branch between Lake street and the junction with the south fork at Bridgeport, as shown on the map. The flow in it, in addition to that which is delivered to it from the north at Lake street, must be that which enters it from point to point along its course, which in dry weather aggregates about 10,000 c. f. m. and in wet weather a still further amount, depending on the rainfall run-off, and reaching in the aggregate a maximum volume not far from 150,000 c. f. m.

If it be a question of simply protecting the water supply, then, with an inflow of 150,000 or 300,000, the outflow to be provided for will be about 300,000 or 450,000, or some volume intermediate according to the intensity of rainfall. It is evident from these figures that the present provision, for 300,000 c. f. m. in South Branch, or 360,000, as required by law, will not be effective in preventing flood waters going out of the main river into the lake, and these waters will carry the foul accumulations of the North Branch, and for the time being render the lake water supply "not usable" or "bad," whichever our health department calls it. Anyone can verify this statement by looking at the main river from the Rush street bridge on the occasion of the next heavy rainfall.

If it be a question of maintaining the South Branch in a sanitary condition, when the North Branch is reduced to that state, then, in addition to the flow from the North Branch there must in some way be introduced from Lake Michigan 20,000 c. f. m. for each 100,000 people, draining into the South Branch, or about 100,000 c. f. m, at the present time. It follows, then, that aside from flood conditions a present flow of 150,000 c. f. m. from the North Branch, and the provision of 100,000 c. f. m. for the South Branch is needed, or a flow of 300,000 c. f. m. in the South Branch, and as time goes on this is to be augmented to more than 200,000 c. f. m. from the North Branch, and doubtless to 150,000 for the South Branch, or a total outflow of 350,000 c. f. m. to 400,000 c. f. m.

It appears from these figures that in giving the South Branch a capacity to flow 300,000 c. f. m., a proper provision has been made to maintain a fair sanitary condition in the North and South Branches in dry or nearly dry weather—which covers the most of the time. But there has not been made ample provision for flood conditions, unless people will be content to have their water supply made doubtful at times. To meet the conditions at flood times its capacity should be quite uniformly increased along its course, since sewers enter it quite uniformly along said course, from 300,000 c. f. m. at Lake street to 450,000 c. f. m. at Bridgeport.

Passing now to the south fork basin, it may be concluded in accordance with well established rules as to the accumulation of flood water in catchment basins, that its maximum flood will have passed before that of the North Branch has reached Bridgeport, and that its influence will be to add to the maximum from the South Branch at Bridgeport, a maximum of 50,000 c. f. m. or more, according to the degree of urban development in its basin, which is not large at present. Its flood waters cannot be at any time diverted to Lake Michigan, but unless the part of the west fork from Ashland avenue to Robey street be made sufficiently capacious to pass the total volume from South Branch and south fork, the tendency will be to back up the South Branch and crowd out North Branch water to the lake. This part of the west fork should have a capacity at flood times of something more than 500,000 c. f. m. The most important feature of this basin, the waters of which are more highly polluted than any others in Chicago, is the entrance of the 39th street conduit at Halsted street. This is intended to deliver 120,000 c. f. m. of water and sewage per minute into that end of the fork, the dilution of the sewage being so high that the combination may be effective in reducing the south fork to a tolerably sanitary state. The dry weather flow of the fork may, therefore, be taken to be 120,000 c. f. m., plus the water supply, which is not large now, but may reach 10,000 c. f. m. or more in the future. This dry weather flow is in excess of the flood volume, and when flood waters are present the flow through the conduit may be checked by slowing down the pumps which feed it, until the flow is no larger than is required by the sanitary conditions pertaining to the sewers along the south shore, which it intercepts. Whether the influence of this flow will reduce the south fork to a sanitary condition remains to be determined. In 1890 the writer had direction of an extensive examination of the contents of this fork, the result of which showed that each gallon of its water contained about ten times the organic elements that were contained in an equal quantity of water from the Illinois & Michigan Canal at the Bridgeport pumps, where the dilution of average Chicago sewage was about 3.5 of lake water to 1 of sewage. The inflow of sewage at the time into the fork was about 10,000,000 gallons per day. The inference is, that this 10,000,000 gallons of sewage would be the equivalent of about 30,000,000 gallons of ordinary sewage, or an amount corresponding to 250,000 to 300,000 people. If these figures be anywhere near right, then the influence of the conduit will probably be to render the condition of the fork tolerable. Be this as it may, it is in a certain sense a problem collateral to the general question of river improvement, and affects only that part of the river between Ashland avenue and Robey street, where no right-of-way problem of moment is involved and where the cost of any improvement will be very small. A dry weather flow of 120,000 c. f. m. may, therefore, be reckoned from the south fork, a quantity which will not be exceeded in flood times, at least, not for many years to come.

Passing now to that part of the river between Ashland avenue and Robey street, where the main drainage canal is entered, there is no appreciable catchment basin tributary thereto. It simply must carry the combined flow from the South Branch and the south fork. If it be a question of maintaining a sanitary condition in the river in dry weather, then the former will vary from 250,000 c. f. m. at the present time to 350,000 or 400,000 c. f. m. in the future. The latter may be taken to be 120,000 c. f. m. The combined dry weather flow will therefore vary from 370,000 c. f. m. at the present time to 470,000 or 520,000 in the future. If it be a question of protecting the water supply, or caring for the flood conditions, then the South Branch contribution will vary from a minimum of 300,000 to a maximum of 450,000, according to the degree of protection provided. The south fork contribution will be as for dry weather, 120,000 c. f. m. The combination will vary from 420,000 to 570,000.

The last of the catchment basins involved is now reached, namely, the west fork, west of Robey street. This delivers its water directly into the main Drainage Canal. It delivers very little sewage now, and probably never will deliver much, because the sewers now tributary to it and future sewers in its basin will ultimately empty directly into the Drainage Canal. Its flood waters will increase the total to be received by the Drainage Canal to an amount somewhat, but not much, exceeding 600,000 c. f. m. if all the flood waters of the Chicago basin be restrained from Lake Michigan. The Drainage and Water Supply Commission of 1886 and 1887, previously referred to, was the body which fixed the capacity of the drainage canal at 600,000 c. f. m. The considerations which determined them to name this volume were two-fold: The more important was the fact that such a capacity was needed to restrain the flood waters from Lake Michigan; and the other was, that such a capacity would provide for the future when the Sanitary District would be the habitation of 3,000,000 people.

What has been said above, pertains to that which is required of the Chicago rivers to conform with sanitary interests. These flow requirements may be condensed, as shown in Table I:

TABLE I.

Various volumes of flow required by Sanitary interest in the several parts of the Chicago river.

PART OF RIVER.	INFLOW—C. F. M.							OUTFLOW. C. F. M.
	39th St. Conduit	Main River and North Branch.	Inlet.	Sewers.	Lawrence Ave.	Fullerton Av.	Total.	Total
North Branch—			178,000				250,000	250,000
Dry Weather—Maximum.			128,000	15,000	45,000	12,000	200,000	200,000
Minimum..			93,000	10,000	45,000	12,000	150,000	150,000
							245,000	245,000
Wet Weathrr—Maximum.				200,000	45,000		295,000	295,000
Minimum..				250,000				150,000
Main River—								
Dry Weather—Maximum.								150,000
Minimum..								50,000
Wet Weather—Maximum.							—200,000	000,000
Minimum..							000,000	000,000
South Branch —								
Dry Weather—Maximum.		200,000	135,000	15,000			350,000	350,000
Minimum..		150,000	140,000	10,000			300,000	300,000
		300,000					300,000	450,000
Wet Weather—Maximum.		250,000		150,000			250,000	400,000
Minimum..		150,000		150,000			300,000	300,000
South Fork—								
Dry Weather—Maximum.							120,000	120,000
Minimum..							120,000	120,000
Wet Weather—Maximum.							120,000	120,000
Minimum.							120,000	120,000
West Fork (Ashland Av. and Robey St.)—							470,000	470,000
Dry Weather—Maximum.							420,000	420,000
Minimum..							570,000	570,000
Wet Weather—Maximum.							520,000	520,000
Minimum..							420,000	420,000
West Fork—								
Wet Weather.............							50,000	50,000

The figures in Table 1 are doubtless substantially the truth. In any event, they will not be modified in any way that will materially alter the conclusions to be drawn from them.

The improvements in the Chicago River for which they call may be briefly summarized as follows:

(1) North Branch.

The introduction into it for its purification of substantially a maximum of 250,000 c.f.m. of water from Lake Michigan, or a minimum of of 150,000 c.f.m. The purpose would be served if it could be introduced along its length at the sewer outfalls. This is clearly impracticable. 12,000 c. f. m. can be had at Fullerton avenue by the existing conduit and 45,000 c. f. m. through the Lawrence avenue conduit under construction. The plan of 1886-87 contemplated an open cut across Lake View from Bowmanville, or an open cut from Bowmanville northward to the west of Evanston and terminating in the lake just north of Evanston. The execution of this last scheme would doubtless afford the most comprehensive solution of the question and would receive favor in Evanston, which needs such a channel to keep its sewage from the lake and the water supply. Be the water secured where it may, it will have to be pumped. If this flow be introduced, then the prism of the branch will have to be enlarged, as was that of the South Branch, to keep the velocity of flow low enough to suit navigation, and also to reduce the head against which the water will have to be pumped.

If the question be simply to protect the water supply, and not purify the river, then no work need be done in the North Branch.

(2) *Main River.*

No work is needed in the main river that can in any sense become a duty on the Sanitary District for purposes of sanitation. It will be noted that if at any time the North Branch be brought to a sanitary condition, the flow in the main river will be quite small.

(3) *South Branch.*

It may be assumed that when the plans hitherto made have been carried out, which is nearly the case, that 300,000 c. f. m. will flow through the South Branch with the 2 foot slope from Lake street to Bridgeport. This is the slope originally contemplated, and actual experience has substantially justified it.

Improvement of the South Branch, from what has been said, may be made with any one of four purposes in view, as follows:

1. Minimum flow for wet weather conditions.
2. Maximum " " " "
3. Minimum " " dry " "
4. Maximum " " " " "

(1) *Minimum flow for wet weather conditions.*

The inflow is to be 150,000 c. f. m. and the outflow 300,000 c. f. m. No further improvement is needful for this case, but it is to be remembered that it involves occasional emptying of large volumes of sewage into the lake and corresponding menace to the water supply.

(2) *Maximum flow for wet weather conditions.*

Inflow (except its own sewer floods) to be 250,000 or 300,000 c. f. m., and total outflow to be 400,000 or 450,000 c. f. m. The prism of the river at the Lake street end is enough, but it should be increased quite uniformly from near Lake street to Bridgeport. No alternative is possible, since at such time all the water flowing will be derived from the immediate catchment basins.

(3) *Minimum flow for dry weather conditions.*

No further improvement of the branch is necessary for this case.

(4) *Maximum flow for dry weather conditions.*

The inflow to the Branch will be 350,000 c. f. m., of which 150,-

000 to 200,000 will come from the North Branch; 50,000 from Lake Michigan through the main river and from 100,000 to 150,000 from Lake Michigan either by way of the main river or in some other way. If the water from Lake Michigan all comes through the main river then the South Branch must have its capacity increased throughout its whole length. It is practicable to introduce the 100,000 to 150,000 c. f. m. required for dilution of the sewage from sewers south of Lake street at some point along the course of the branch, as, for instance, in the vicinity of Eighteenth street, where the distance from the branch to the lake is about one mile. If such a course is adopted then no further improvement of the river north of 18th street is needed, but its capacity south of 18th street should be increased throughout the two miles or more of its length to 350,000 c. f. m. The water to be introduced at 18th street may come either by gravity through an open or closed channel, or may be pumped through a conduit by means of pumps at either end, or at some intermediate point on conduit.

It will be interesting to examine the consequences that will follow from the adoption of either one of these modes of inlet from the lake. In order to be definite, let it be assumed that 200,000 cu. ft. is to enter the South Branch at Lake street and 150,000 to be introduced at 18th street. Experience has shown that when the level of Lake Michigan is at Chicago datum, then substantially one foot of slope is needed to create a flow of 300,000 c. f. m. from the lake to 18th street. Now, since the change of cross-section will be so small, if the flow be reduced to 200,000 it may be concluded that, for such a flow, the slope will be reduced in the ratio of 9 to 4, which will make it .44 ft. Again, the conditions existing when the lake is at its higher stages must be met, say 4 feet above Chicago datum.

Suppose the inlet channel be such that water flows through it by gravity and that such a channel have a wet cross-section such that its depth is half its width, which is the cross-section of maximum efficiency. Also, suppose the stage of Lake Michigan be at Chicago datum. Then the dimensions of the channel will be substantially 43 feet wide by 21 feet deep. Such a channel will require side retaining walls, and should be covered, which would call for an excavation about 65 feet wide by 37 feet deep. In all probability it may be found less expensive to make such a channel wider and more shallow. The width of any channel of this character that might be constructed, even if its capacity was as little as 100,000 c. f. m., would be such as to render the acquisition of right of way necessary. And, after having acquired this right of way, the experience with the construction of the by-pass around the bridges at Jackson, Adams and Van Buren streets, leads to the conclusion that the cost of such a channel, 6,000 feet long, would not be less than $2,000,000. The by-passes are 50 feet wide by 16 feet deep in wet cross-section, and were built where the ground was from 5 to 7 feet above datum, instead of 15 feet as would be the case along 18th street. The right of way for the 18th street channel would involve something like 3,000 feet of private property. The actual value of the private property would doubtless exceed $1,200,000 (at $400 per front foot), and its acquisition, together with the privilege of occupying railroad property, considering legal expenses, delays, etc., would doubtless cost in excess of $2,000,000, thus involving a total cost of $4,000,000.

During flood times this gravity channel would always deliver into the South Branch an amount of lake water depending on what slope might have existence in the South Branch between Lake street and 18th street. If this slope be nothing, then the whole North Branch flow must go to Lake Michigan. As this slope increases, the gravity channel would deliver into the river about 1.5 cu. ft. for each 2 cu. ft. flowing in the South Branch north of 18th street, if the lake be at or about datum. If the North Branch flood should reach 200,000 c. f. m., the lake being at datum, then 150,000 c. f. m. must come through the gravity channel. Add now to this flow of 350,000 c. f. m. the flood volume from the South Branch basin, 150,000 c. f. m. and we have 500,000 c. f. m. as the outflow of the South Branch. Add now the estimated flow of 170,000 c. f. m. from the south fork and west fork and we have 670,000 c. f. m. delivered to the main drainage channel, the capacity of which, when completed between Robey street and Summit, will be but little more than 600,000 c. f. m. It follows, therefore, that the flow of North Branch water into Lake Michigan will approximate 70,000 c. f. m. plus whatever the North Branch flood waters may exceed 200,000 c. f. m., say a total of 170,000 to 220,000 c. f. m. Maybe this condition will not occur oftener than every year or two. It is a good condition to be rid of, if it can be accomplished, and especially if it can be accomplished at less cost.

Suppose now, that instead of a gravity inlet at 18th street a conduit be built similar to that under construction in 39th street. The maximum velocity in such a conduit may be taken to be 6 feet per second, substantially the same as for 39th street conduit. Its diameter will be 23 feet. The slope of the conduit, or rather the head to be pumped against, if pumps be used, will be substantially 2.75 feet. The cost of such a conduit, according to the experience at 39th street, would be about $1,000,000 and no right of way, with its attendant delays and vexations would be needed, because a street could be occupied. The pumping plant would work against 770 horse power in water column, say 1,500 indicated horse power at most. Such a plant should not cost more than $150,000, but let it be $250,000 to allow for a surplus of fancy work. As to operating such a pumping plant, without meaning any disrespect to the antiquated layout we now have at Bridgeport, we may take as a criterion the performance of the Milwaukee River Flushing Works in September and October 1897, some years after said plant had been operating; and after making liberal allowance for everything it is hard to figure up $40,000 per year as the annual expense to be expected, which we may take as the interest on $1,000,000. Allow 5 per cent depreciation in pumping plant and we can sum up the cost of the whole arrangement as follows:

Conduit	$1,000,000
Machinery	250,000
Capital, account pumping	1,000,000
Depreciation (capitalized)	312,500
	$2,562,500

This is very much less than the cost of a gravity channel, and much preferable. No right of way is involved. Construction could be commenced at once. Its flow can always be controlled to suit flood conditions.

Two such conduits, together with that at 39th street, and a flow of 180,000 c. f. m. through the main river and South Branch to 18th street, and some other street where the other conduit might be, would put 600,000 c. f. m. into the main drainage canal.

Examining further the consequences of a gravity inlet along 18th street, or its vicinity, it is interesting to note how it will behave at differing lake levels. It is not extreme by any means to hold in view a level of the lake at 4 feet above datum for a considerable period. Let us still have in mind a flow of 200,000 c. f. m. through the South Branch from Lake street to 18th street, which is certainly as small as ought to be contemplated. When the lake is 4 feet above datum the river will have a small slope with this amount flowing because its cross-section and hydraulic radius is larger. Knowing from experience what the slope is when 300,000 is flowing, with the lake at datum, the slope when 200,000 is flowing can be very closely determined. The former slope being 1 foot, the latter will be 0.44 feet. Now, whether the velocity of the flow will vary in the first, or the one-half, or some intermediate power of hydraulic radius, will make little difference in computing the slope for the same flow and the channel 4 feet deeper. Furthermore, the whole variation of hydraulic radius is within such limits and of such magnitude that the Chezy formula can be used in these computations and give substantially identical results as given by any other formulæ. We know from experiment that the Chezy formula for the South Branch is $v=50\, r^{1/2} s^{1/2}$ and we know that for an inlet channel of straight alignment and smooth sides that the proper formula will be substantially $v=100\, r^{1/2} s^{1/2}$. Any variations that can be made from these formulæ will not alter the conclusions to follow. And still again, just to the extent that hydraulic formulæ are uncertain, just to that extent will there be uncertainty as to the result that will come from a gravity inlet. An average section of the South Branch between Lake street and 18th street, of 160 feet by 20 feet with the lake at datum, is called for by the flow, slope and formula above noted. It follows, also, that if the flow from the main drainage canal at Lockport be regulated so as to cause 200,000 c. f. m. to flow at all times between lake and 18th streets, then,

(a) If the inlet channel be 43 feet by 21 feet, with lake at datum and flow 150,000 c. f. m., its flow with lake 4 feet above datum will be 88,000 c. f. m.

(b) If it be 75 feet wide by 21 feet deep, with lake at datum and flow 300,000 c. f. m., then its flow with the lake 4 feet above datum will be 177,000 c. f. m.

(c) If it be 120 feet wide by 21 feet deep, with the lake at datum and the flow be 505,000 c. f. m., then its flow will be 300,000 c. f. m. with the lake 4 feet above datum.

If the flow at the regulating works at Lockport be maintained constant, as required by law, then no matter what the size of the inlet channel, the flow through it as the lake is higher will diminish and the flow through the South Branch north of 18th street will increase. This is favorable to flood disposal, but objectionable to navigation interests. If the smaller inlet, case (a), be made, then at higher lake levels the South Branch flow, north of 18th street will be about 230,000. If case (b) be built, then 250,000 c. f. m. will be the flow.

The worst feature is the crowding of North Branch sewage into Lake Michigan in flood time. The South Branch improvements, by diminishing the fall of water surface from the lake to the main drainage canal will have the effect of increasing the capacity of the latter by not more than 50,000 c. f. m. when the lake is at datum, so its capacity may be estimated to be 650,000 c. f. m. But if 200,000 c. f. m. of the North Branch flood is to be cared for, then 300,000 c. f. m. of lake water must also be cared for when lake is at datum. This, together with 150,000 c. f. m. from the South Branch basin and 170,000 from south fork and west fork, means an inflow to the canal amounting to 820,000 c. f. m., which is impossible. This means a flow of some 250,000, or nearly the total North Branch sewage into the lake.

If an inlet channel be made which will assure 300,000 c. f. m. at high lake level, case (c), it is evident that at low lake level there would be very little flow in the South Branch north of 18th street at any time, and the North Branch sewage would at substantially all times of rainfall, have vent into Lake Michigan.

The gravity inlet is attended by many complications, difficulties and uncertainties, all of which may be avoided by building conduits through which water is to be pumped, and for which the expense will be less.

The idea of introducing 300,000 c. f. m., by an inlet near 18th street, considering its difficulties and cost, brings forcibly to the front the idea of introducing it through the main Chicago River. This involves giving the South Branch and main river a capacity of about 500,000 c. f. m. throughout their whole length. Say a channel, 200 feet wide and 25 feet deep. The writer, in April last, acting as chief engineer of the Sanitary District, prepared an estimate of the cost of such an undertaking for one of the trustees and made it about $12,000,000, and these figures have since been used freely. As he remembers it now, aside from bridging which will have to be done anyhow, about $8,000,000 or $9,000,000 of this amount applied to the river between Lake Michigan and 18th street. It is a common error to suppose that the right of way for such a work will be very expensive. The area of land to be acquired is really quite small, compared to the area to be acquired for an inlet channel, though the price, per unit of area, is considerably more. It may be said that, the inlet channel being covered, it could be occupied after the completion of the inlet. If this occupation should be of a nature to give the land a value approximating to its cost, the covering would have to be quite substantial indeed, and very expensive.

Considering, also, that no matter how an inlet channel may be constructed, it can in no way provide for maximum flood requirements between Lake street and the inlet, it is indeed a very serious question whether it would not be better to make the whole improvement in the rivers, as the more recent plans of the Sanitary District contemplate. But if it must be an inlet, then the conduit idea would seem to be preferable to a gravity inlet—unless, indeed, the ultimate closing of the main river be contemplated.

The improvement needed for the South Branch, to meet the case now being discussed, may now be summarized as follows: Nothing need be done north of 18th street. A gravity channel or pumping conduit may be made from Lake Michigan to the branch at 18th street. The branch south of 18th street to be enlarged to a capacity of 350,000 c. f. m.

As far as improving the South Branch in the interest of sanitation is concerned, the matter may be summarized thus:

(a) Increase of capacity along its course from 300,000 c. f. m. at Lake street, to a quantity approximating 450,000 c. f. m. at Bridgeport, according to the degree of protection that is desired in preventing flood waters entering the lake.

(b) An improvement to meet maximum future requirements for river purification, which may be accomplished by increase of capacity somewhat toward the Bridgeport end, with or without introduction of lake water at 18th street or some intermediate point.

(4) *South fork.*

It is not likely that any further improvement of the south fork will be needed, except the completion of the 39th street conduit project.

(5) *West fork.*

The capacity of the west fork, from near Ashland avenue to Robey street at the junction with the Drainage Canal, will need enlargement to take care of both South Branch and south fork flow, both in dry and wet weather, which means to give it a capacity of about 550,000 c. f. m.

It will be noticed that the figures given for maximum flow in dry weather do not take into consideration any water from Lake Michigan to dilute the sewage from the west fork and from the south fork, in excess of what may be properly diluted by flow from 39th street conduit. This omission was made in order to simplify an already complicated discussion. The amount of water thus needed will be 130,000 c. f. m. when the population of the Sanitary District has become 3,000,000. No doubt its introduction can best be effected either through the main river or by either inlet to the South Branch. The consequence will be to call for a larger improvement in the South Branch, either throughout the whole length of the branch, or throughout the part southward from any inlet that may be made. The conditions will be satisfied by a flow of 200,000 from North Branch; 50,000 from main river; 190,000 from inlet (gravity or pumping) at 18th street; 120,000 from 39th street conduit; and 40,000 from sewers, since such a quantity will be their minimum flow when the population is 3,000,000. Any deviation from these figures that will tend to diminish the flow from the North Branch and main river will tend to defeat river purification, and will tend to crowd the North Branch sewage into Lake Michigan.

Navigation Interests.

Next to sanitary interest, navigation interests are doubtless the most important, and it is right and proper to so modify the improvements demanded by sanitation in such a way as not to affect their usefulness, but at the same time assure no obstacle to navigation. It will be conceded that navigation will be inconvenienced in some degree by the velocity of flow that will have existence in the river; the same velocity will, in some measure, hinder the entrance of the several slips along the river. The consequence of either is a greater or less increased cost of transportation. Navigation interests must in some degree be affected by these things. It is unavoidable. No doubt some navigation interests will object, no matter what is done to compensate them for the injury. The only thing that it is possible to do is to offset this injury with some compensating advantage in another form, say by cash subsidy, or greater depth of channel, or greater width, or improved bridge openings.

The plans for improving the Chicago River, made by the writer and approved by the Chief Engineer and Board of Trustees of the Sanitary District, were based on a dictum of the authorities that provision should be made for a flow of 300,000 c. f. m. at time of low lake level, through the whole length of the South Branch and west fork to the Drainage Canal at Robey street; the available head of water or difference of level between the lake and Robey street being about two feet. It so happened that to accomplish this, the prism of the river had to be increased to an extent that gave a depth of 20 feet, a minimum width of 140 feet, and an average mean velocity of about one and one-fourth miles per hour. This improvement of the river, while not yet complete, has been so far executed as to justify all that was promised for it. Some boats have had trouble in the river, but, so far as the writer knows, these troubles occurred almost entirely at localities where the plans had not been executed or where the river was unreasonably obstructed by cofferdams for new bridge work. Much has been said about the Washington street tunnel as an obstruction to navigation. It was built long before the improvement of the river, and is no more of an obstruction than it always has been. The effect of the flow in the river of 300,000 c. f. m. has been to lower the water at that point about one-tenth of a foot only. As a matter of fact, the expenditure of $10,000 or $20,000 at this point can easily be made to effect an increase of between one and two feet to the available navigable depth, and the writer is somewhat puzzled to know why, in view of all that has been said about this obstruction, those who strenuously air their troubles at this place do not mention this possible improvement. It is quite true, that if full advantage is to be taken of the depth of 20 feet in the rest of the river the tunnel should be lowered. If this should be done, however, navigators might perhaps load their boats deeper and drag the whole length of the river, and cause the velocity of flow to be a great injury, thus bringing odium upon the river works.

There is no doubt in the writer's mind but that the facts pertaining to the effect of the flow during the past year have been misunderstood and possibly exaggerated in the interests represented by the fault-finders. One critic has found fault because the river did not conveniently carry 360,000, when it was designed for a flow of 300,000. An official of the Sanitary District has recently given out that 300,000 c. f. m. is flowing through the river, when the flow was really between 350,000 and 400,000 c. f. m. Such has been the case now for about two months, as the writer has been practically able to observe daily at dam No. 1, at Jackson street in Joliet, where he is building a water power plant. Navigators say that the corresponding current is objectionable, and nobody ever said it would not be. The river was not designed for any such flow. Much has been said about the increased cost of moving boats in the river, but the writer doubts if a close study of the facts will furnish full justification. There is no doubt but that there is some difficulty entering slips, compared with what existed formerly. Slips are private property, and the troubles therein can not be fairly classed as injury to public navigation. The Sanitary District has power to deal with them just as it has with other private owners. The writer has yet to learn of any praise of the advantages accruing to navigation from the works of the Sanitary District, such as removal of Canal street and other bridges, the widening, deepening and straightening of the river, that has been done.

The writer believes as thoroughly as any one in conserving and fostering navigation interests, but leans to the opinion that it should be done on its real merits and in a proper way. Whether the city of Chicago is now under obligation to make large expenditures for this specific purpose, he questions. In developing the sanitary works it would seem that the principal obligation is to see that any inconvenience created be offset with some equivalent compensating advantage. Just what will be satisfactory to navigation interests. is undetermined. They have not as yet named any criterion as a guide. It is utterly impossible to eliminate entirely the inconvenience of which they complain.

Enlargement of the river prism will cause a state of affairs approximating their wishes, and if their interests and influence are strong enough to have Chicago make the expenditure, then the question will turn on the best method of procedure. The class of work to be done will be of the same class as that required by sanitation. The volumes of flow to be provided for will be the same.

The problem is to reduce velocity, but at the same time preserve the volume of flow everywhere.

The legal requirements for flow through the Drainage Canal are 360,000 c. f. m., and will ultimately be 600,000 c. f. m. A flow of 120,000 c. f. m. from 39th street conduit and 240,000 through the South Branch meet the present requirements, and would make the velocity in the South Branch about two-thirds that now existing. Maybe this would be satisfactory to the objecting navigators, and in any event it might be a good and consistent idea for them to promote the completion of the conduit as vigorously as they have objected to the flow in the river, but so far they have notdone so.

The Sanitary District has for some months been contemplating an enlargement of the South Branch through its whole length to about a width of 200 feet by 25 feet deep. This would effect a present reduction of velocity in the river that would be very material, and give vessels more "sea room" at most places. However, as time goes on and the flow increases, the velocity of current will increase and will ultimately become as objectionable as will exist now with 300,000. Of course, navigators will have the offsetting advantage of greater width and depth, and it is to be hoped this fact will satisfy them. Inlets at 18th street would then have to be made in addition—or some equivalent work be done.

Inasmuch as there must be much doubt as to what will ultimately be satisfactory to the navigation interests, and that the result of any work done may prove unsatisfactory after a heavy expenditure for right of way and docks built in wrong places, perhaps the wise way would be to go at the matter progressively. Say, enlarge the river south of 18th street considerably, where right of way is not expensive. Make an inlet at 18th street of 150,000 c. f. m. capacity, preferably a pumping inlet, because it enables a control of velocity and flow in the river, both in reference to sanitation and navigation, which is utterly impossible with a gravity inlet. Again, it is the least expensive. As time goes on and increased flow is needed for sanitation, another conduit can be built. The enlargement of the river south of 18th street, to meet requirements for 600,000 c. f. m. flow in the Drainage Canal should be such as to make a low velocity at that time—give it a prism 300 feet wide by 30 feet deep, for instance. Perhaps it would be just as well to secure right of way for this now, and construct but part of the prism, though, as a matter of fact, the difference in cost between any thing that can be done now and the large prism will not be large.

It would be more equitable, however, if the general government could be persuaded to join in this work, if the precedents set elsewhere are of any use.

DISCUSSION.

BY MR. ISHAM RANDOLPH.

I must refrain from any discussion of Mr. Johnston's paper. There are conditions which keep me from stating wherein I agree or wherein I differ with the author and my reasons for so agreeing or differing. I greatly regret Mr. Johnston's absence from this meeting, for had he been here I am sure that he would have relieved me of the seeming necessity of occupying any of the time of this assembly. There are certain statements in the paper which scarcely accord with the facts, and as a matter of course it would only have been necessary to bring the facts to his attention to insure a willing correction.

In the latter part of March and early days of April, 1900, I prepared a map of a proposed improvement of the Chicago river, based upon a width of 200 feet and a depth of 26 feet. Throughout certain portions of the river there were alternative suggestions for the taking of land necessary for this widening; the determination of the side to be used had to be reached largely through the relative cost of properties on the east or west sides of the river. On the 4th of April, 1900, two resolutions were introduced at a meeting of the Board of Trustees covering this improvement—one by Trustee Wenter, the other by Trustee Jones. On some matters these resolutions differed materially, but each provided for a river 200 feet wide and 26 feet deep. Having had a vacation granted me by the Board for a much needed rest, I left for New York on the afternoon of the day these resolutions were introduced. Before leaving, however, I advised Mr. Johnston fully of what was wanted in developing the plans I had entered upon, and left him to complete the estimates. These he completed and reported to the Board of Trustees under date of April 9th, giving a resulting approximation of cost of $11,132,738 for the west side and $11,092,085 for the east side. The Board took action on the 11th of April, declaring in favor of a 200 foot channel 30 feet deep, and instructing the Chief Engineer to prepare estimates for such an improvement. Since that time a considerable amount of property has been purchased south of 12th street, and a contract has been awarded covering all of the work to be done under this project from the date of its execution—September 21, 1900, to January 1, 1902; the depth of dredging under this contract to be not less than 20 feet nor more than 26 feet below the flow line. This is the only wide river project ever adopted by the Sanitary District.*

The statement that the Sanitary District has been flowing between 350,000 and 400,000 cubic feet per minute for two months last past is an error, as is shown by our records, carefully kept and known to be accurate within a very small percentage. The greatest flow within this period of which we have any record was on the 26th of December, when, on a rising lake, the flow measurements made below 18th street by Mr. Keating showed 347,843 as the average of the measurements taken. The weekly averages were as follows:

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*This statement of the facts by Mr. Randolph was called out by what subsequently turned out to be a typographical error in the advance copy of Mr. Johnston's paper.—EDITOR.

Average Weekly Rate of Flow in Cubic Feet per Minute.

	Week Ending	No. of Week.	I. & M. Canal at Bridgeport.	Main Channel near Lockport	Chicago River	Desplaines River at Riverside.	Dam No. 1 Joliet.
1900			I	L	C	R	J
Dec.	1	48	23,086	235,825	258,911	19,628	278,539
	8	49	23,162	224,214	247,376	10,723	258,099
	15	50	23,124	234,375	257,499	6,660	264,159
	22	51	11,457	241,646	253,103	4,800	257,903
	29	52	0	323,123	323,123	3,960	327,083
Jan.	5	1	0	278,860	C-L	2,640	281,500
1901	12	2	0	317,717		1,774	319,491
	19	3	0	232,979		3,827	236,806
	26	4	0	315,396		4,885	320,281
Feb	2	5	0	317,368		2,640	320,008

Taking up the paragraph relating to the Washington street tunnel, much good would result to navigation interests if the superfluous brick work on top of the flattened arch was removed. This improvement I have urged for months, and I now have authority from the Board of Trustees to do the work at the expense of the Sanitary District; but, so far, I have been unable to secure a permit from the city allowing me to proceed. This, however, I hope soon to have. I propose using a pile driver equipped for cutting off piles below water. A diamond drill will be fixed to the mandrel from which the circular saw has been removed. With this diamond drill I propose to honeycomb the brick work so that divers may break it up by using wedges. This done and the debris removed, vessels of the widest beam entering this port can get the full benefit of whatever depth of water may obtain over the tunnel. This treatment will be applied only to the west opening at this time. Mr. Johnston errs in giving the loss of depth over this tunnel as only one-tenth of a foot. I have personally known it to reach four-tenths.

Regretting that it should have been necessary for me to take issue with any statements contained in this interesting paper, and thanking you for the attention you have given to my remarks, I yield the platform to the next speaker.

NOTES ON "THE CHICAGO RIVER."

By Ernest L. Cooley.

I.

The writer of these notes regrets that it is necessary to make them. Since the printed paper on "The Chicago River," by Thos. T. Johnston, M. W. S. E., records statements which conflict with the records of the Engineering Department of the Sanitary District, it cannot be passed over in silence. The extensive and conscientious work of a number of trained and experienced men is not to be impeached by the unsupported assertion of a gentleman who was absent most of the time the work in question was going on.

It is not the purpose of the writer to question motives, and what he has to write he proposes to write briefly and to the point. On the merits of the case many of the statements in the paper are true, but many are not true. Some of the statements are so hedged about by verbiage that it becomes necesssary to dissect them for the better information of those who do not know the history of the subject under review. It is remarkable that the statements in the paper contain so many errors in fact. The data of the Sanitary District are quite voluminous and were accessible to the author. Certain points will be taken up seriatim and as briefly as possible.

II.

On pages 332-6 the author introduces a hypothetical channel from Lake Michigan to the Chicago river at 18th street. He assumes a "channel 6,000 feet long," while the distance on the map is only 4,400 feet. He assumes a gravity channel without any controlling works, which is absurd in this case. After making various assumptions and after going through several pages of involved reasoning, he makes the deduction that when Lake Michigan is four feet above datum, the "gravity channel" on 18th street will discharge only about 59 per cent what it will discharge with Lake Michigan at datum. In other words, after increasing the depth of the gravity channel from 21 feet to 25 feet, and its area 19 per cent, it will, with his assumptions, discharge only 59 per cent. of the water. It would be curious to know how much *more* this hypothetical channel, with similar assumptions, would discharge with Lake Michigan four feet *below* datum.

On the merits of the question the author's discussion is not germane, because no engineer would seriously propose a gravity channel at 18th street without proper controlling works. If the author had taken a leaf out of Chief Engineer Randolph's reports of 1895-7, he would not have fallen into this blunder. Referring to the Proceedings of the Board of Trustees of the Sanitary District of Chicago for 1897, page 4231, Mr. Randolph, among other things, says of the 39th street conduit:

"Should this project be favorably considered on its merits, the demerit of a possible reversal of flow under abnormal conditions can be met so obviously and inexpensively by the use of gates that I did not think it necessary to discuss it."

Mr. Randolph's reasoning applies with equal force to the inlet channel at 18th street. It is obvious that with intelligent design an open gravity inlet channel at 16th or 17th street, with proper controlling works, can be made to pass any desired flow from nothing up to the full capacity of the river below, subject to regulation at a moment's notice and without the use of pumps. Moreover, a properly designed open gravity channel, with controlling works, to carry 600,000 c. f. m., or more, can be built and operated as an investment for much less of the people's money than one or more closed pumping conduits, when 300,000 c. f. m., or more, of water are to be passed through.

The closed conduit idea was originally promoted by Mr. Gordon Knott as a solution of the Chicago sanitary problem, before the plan of the open gravity drainage canal was recommended on its merits by the Chicago Drainage and Water Supply Commission of 1886-7. The author refers to this commission four times in his paper in terms of much respect. The engineering reasons which led to the recommendation and adoption of the plan for the open gravity drainage canal are still good and sufficient. It will surprise many of the engineering friends of the drainage canal to learn that since closed conduits, pumps and water power have become a diversion, the open gravity drainage canal as originally planned and adopted has fallen into disrepute.

The writer of these notes is not an advocate of an inlet channel as the only or the best solution of the problem, but merely wishes to have the question treated on its merits.

III.

The author, in his chapter headed Navigation Interests, on page 338, says, among other things:

"Some boats have had trouble in the river, but so far as the writer knows, these troubles occurred almost entirely at localities where the plans had not been executed, or where the river was unreasonably obstructed by cofferdams for new bridge work." It has been the business of the writer of these notes to calculate the flow through the Chicago river for each day since the opening of the canal, and he wishes to state that never within his knowledge has a large boat successfully navigated the current of the Chicago river at any time or place below Rush street bridge in a current flowing so large as 300,000 c. f. m. Moreover, quite a number of boats have had trouble when the flow was much less than 300,000 c. f. m., and in portions of the river that were supposed to be passable in the author's plans. The average daily rate of flow through the Chicago river for the second and third quarters, by weeks, from April 1 to September 29, 1900, is 210,600 c. f. m. The average for the season of navigation is slightly larger than this. The average for the full 49 weeks of 1900 since the canal was opened is 214,900 c. f. m. There are only three days during the season of navigation since the canal was opened, on January 17, 1900, when the average daily rate of flow through the Chicago river was equal to or more than 300,000 c. f. m. One of the three days (Saturday, June 16, 1900) was an experiment by request of the U. S. Engineer, and the average rate of flow was 311,700, as indicated at Lockport and through the Illinois and Michigan canal. The navigation interests were warned on this occasion and did not move any large boats until the flow was reduced. It is but fair to state that the difficulties of navigating the current of the Chicago river have been much underestimated by the author.

On page 338 the statement is made that "for a flow of 300,000 c.f.m. at time of low lake level, . . . the available head of water or difference of level between the lake and Robey street is about two feet." The only authority the writer of these notes can find for this statement is an official report on the "Capacity of the Chicago River," made by Mr. Johnston under date of November 18, 1899, about two months before the drainage canal was "opened" and before the slope in question came into being. On page 6126 of the Proceedings of the Board of Trustees of the Sanitary District, among other things, he says: " That if the flow be 300,000 cu. ft. per minute, the declivity of the water surface will be but two feet" from Lake Michigan to Robey street. A profile appended to this report, and made under the direction of its writer, puts the difference in level two and one-half feet. Now the facts are that a considerable number of actual measurements made by the Engineering Department of the Sanitary District show conclusively that this slope in question lies between the limits of two and one-half and three feet (2.8 feet in several cases), with the lake level about datum and the river flowing 300,000 c. f. m. and free from ice.

On the same page, and further down, the statement is made of the Washington street tunnel, that it is not " any more of an obstruction (to navigation) than it ever has been. The effect of the flow in the river of 300,000 c. f. m. has been to lower the water at that point about one-tenth of a foot only." This statement is not even approximately true. The fact is that with the lake about datum, and with 300,000 c. f. m. flowing through the river, the water surface over the Washington street tunnel is lowered half a foot by actual measurements and with the river free from ice.

IV.

On page 339 the author says:

" There is no doubt in the writer's mind but that the facts pertaining to the effect of the flow during the past year have been misunderstood, and possibly exaggerated, in the interests represented by the fault-finders. One critic has found fault because the river did not conveniently carry 360,000, when it was designed for a flow of 300,000. An official of the Sanitary District has recently given out that 300,000 c. f. m. is flowing through the river, when the flow was really between 350,000 and 400,000 c. f. m.

Such has been the case now for about two months, as the writer has been practically able to observe daily at dam No. 1 at Jackson street in Joliet, where he is building a water power plant."

The only obvious fact in the above quoted paragraph is the "doubt in the writer's mind." The following tabulation of the average daily and weekly rate of flow for the last four weeks of 1900 and the first six weeks of 1901, covering the case "for about two months" before date of paper, shows how far the author was from the truth:

D—Day of the month; day of the week.

I—Flow of Illinois & Michigan Canal, estimated from three daily readings, reduced to canal lock gauge near Bridgeport pumps.

L—Flow through Main Channel, estimated from forty-eight half-hour readings daily at Controlling Works, near Lockport, Illinois.

C—Flow through Chicago River, being sum of **I** at Bridgeport and **L** at Lockport, 29 miles below; without corrections for time intervals.

R—Flow of Desplaines River at Riverside, estimated from two daily readings on the Riverside Gauge.

J—Flow at Dam No. 1, Joliet, being sum of **I**, 33 miles above; **L**, 4 miles above, and **R**, 28 miles above; without corrections for time intervals.

DECEMBER, 1900

D		I	L	C	R	J
2	S	23200	233394	256594	13980	270574
3	M	23200	240065	263265	13080	276345
4	T	23200	176894	200094	11040	211134
5	W	23200	232681	255881	9840	265721
6	T	22933	233469	256402	9840	266242
7	F	23200	241442	264642	8640	273282
8	S	23200	211556	234756	8640	243396
		162133	1569501	1731634	75060	1806694
Weekly Average		23162	224214	247376	10723	258099
9	S	23200	216044	239244	8640	247884
10	M	23200	233811	257011	8640	265651
11	T	23200	236531	259731	6660	266391
12	W	23200	235308	258508	6660	265168
13	T	23200	242492	265692	5340	271032
14	F	23200	238994	262194	5340	267534
15	S	22667	237446	260113	5340	265453
		161867	1640626	1802493	46620	1849113
Weekly Average		23124	234375	257499	6660	264159
16	S	22400	235059	257459	5340	262799
17	M	22400	232183	254583	5340	259923
18	T	21433	230271	251704	5340	257044
19	W	13967	236477	250444	5040	255484
20	T	00 0	250456	250456	4620	255076
21	F		251492	251492	3960	255452
22	S		255582	255582	3960	259542
		80200	1691520	1771720	33600	1805320
Weekly Average		11457	241646	253103	4800	257903

D		I	L	C	R	J
23	S	00000	287498	C.= L.	3960	291458
24	M	. . .	317076	. . .	3960	321036
25	T	. . .	328967	. . .	3960	332927
26	W	. . .	336004	. . .	3960	339964
27	T	. . .	326712	. . .	3960	330672
28	F	. . .	329150	. . .	3960	333110
29	S	. . .	336454	. . .	3960	340414
		0 0	2261861		27720	2289581
Weekly Average		0 0	323123		3960	327083
30	S	000000	247858	C.= L.	2640	250498
31	M	. . .	222483	. . .	2640	225123
JANUARY 1901						
1	T	. . .	298048	. . .	2640	300688
2	W	. . .	298058	. . .	2640	300698
3	T	. . .	299304	. . .	2640	301944
4	F	. . .	290269	. . .	2640	292909
5	S	. . .	296002	. . .	2640	298642
			1952022	. . .	18480	1970502
Weekly Average			278860	. . .	2640	281500
6	S	. . .	300452	. . . .	2640	303092
7	M	. . .	291540	. . . .	2340	293880
8	T	. . .	334444	. . . .	1920	336364
9	W	. . .	344527	. . . .	1920	346447
10	T	. . .	329366	. . . .	1320	330686
11	F	. . .	315824	. . . .	1080	316904
12	S	. . .	307865	. . . .	1200	309065
		. . .	2224018	. . . .	12420	2236438
Weekly Average		. . .	317717	. . . .	1774	319491
13	S	. . .	304177	. . . .	1320	305497
14	M	. . .	261172	. . . .	2970	264142
15	T	. . .	176797	. . . .	4290	181087
16	W	. . .	173927	. . . .	5340	179267
17	T	. . .	179771	. . . .	4620	184391
18	F	. . .	240590	. . . .	4290	244880
19	S	. . .	293123	. . . .	3960	297083
			1629557		26790	1656347
Weekly Average			232794		3827	236621
20	S	. . .	276619	. . . .	3960	280579
21	M	. . .	313083	. . . .	4980	318063
22	T	. . .	328500	. . . .	6330	334830
23	W	. . .	323033	. . . .	6000	329033
24	T	. . .	316683	. . . .	5340	322023
25	F	. . .	337378	. . . .	4290	341668
26	S	. . .	312473	. . . .	3300	315773
			2207769		34200	2241969
Weekly Average			315396		4885	320281

—D—		I	L	C	R	J
27	S	. . .	321817	C = L	2640	324457
28	M	. . .	324646	. . . .	2640	327286
29	T	. . .	314456	. . . .	2640	317096
30	W	. . .	330415	. . . .	2640	333055
31	T	. . .	318033	. . . .	2640	320673
FEBRUARY						
1	F	. . .	305200	. . . .	2640	307840
2	S	. . .	307006	. . . .	2640	309646
			2221573		18480	2240053
Weekly Average			317368		2640	320008
3	S	. . .	328608	. . . .	.2640	331248
4	M	. . .	335221	. . . .	2640	337861
5	T	. . .	307325	. . . .	2640	309965
6	W	. . .	299702	. . . .	2640	302342
7	T	. . .	302650	. . . .	2640	305290
8	F	. . .	250160	. . . .	2640	252800
9	S	. . .	239202	. . . .	2640	241842
			2062868		18480	2081348
Weekly Average			294695		2640	297335

For the week ending December 29th, 1900, the average flow was 323,000 c. f. m., and this is the largest average weekly flow up to date of this paper. An examination of the data shows that there is no evidence that the flow of the Chicago river "was really between 350,000 and 400,000 c. f. m." for a single day, to say nothing of its having been so "for about two months."

Mr. W. T. Keating, M. W. S. E., made several flow measurements in the Chicago river during the period of maximum flow, and the largest of these measurements was less than 350,000 c. f. m., and was made while the lake was rising rapidly. This condition lasted for an hour or two and was abnormal. A study of the data shows that this flow measured by Mr. Keating was probably the largest flow passing through the Chicago river from the time the canal was opened up to the date of the reading of the paper, February 13th, 1901.

During the months of January and March, 1901, and in 1900, the Engineering Department of the Sanitary District made quite a large number of flow measurements, over one hundred in all, in the Chicago river and near Lockport; 6 in the Chicago river and 53 at Lockport in 1901, and about as many more in 1900, to say nothing of 35 or 40 made in the Chicago river by the U. S. Engineers. The average daily rate of flow at Lockport was determined from 48 half-hour observations, and it is safe to say that with a flow of about 300,000 c. f. m. the tables used give one or two per cent. too much over the bear-trap dams and three or four per cent. too much through the sluice gates. These are outside figures. The writer believes, from a study of the data, that the average difference will not be more than half the above limits. Mr. W. T. Keating had general charge of these flow measurements and Mr. W. M. McCartney has done the field work at Lockport. Mr. E. H. Heilbron made quite a number of measurements in 1900. Mr. E. T. Erikson has done valuable work in checking the gauges in Chicago river. The above named gentlemen are all members of the Western Society of Engineers.

On page 340 the author says:

"Make an inlet at 18th street of 150,000 c. f. m. capacity, preferably a pumping inlet, because it enables a control of velocity and flow in the river, both in reference to sanitation and navigation, which is utterly impossible with a gravity inlet. Again, it is the least expensive. As time goes on and increased flow is needed for sanitation, another conduit can be built."

The writer has briefly pointed out in section II of these notes that an open gravity inlet, with proper controlling works, can be made to furnish as little or as much water as desired up to the full capacity of the main drainage channel, and at the same time be cheaper as an investment than the two pumping inlets mentioned above. The cost of the pumping machinery, with perpetual and large operating expenses in the case of the pumping inlets, much more than offset the costs due to right of way and fixed crossings for all streets and railroads in the case of the open gravity channel.

On the last page the author says:

"The enlargement of the river south of 18th street to meet requirements for 600,000 c. f. m. flow in the Drainage Canal should be such as to make a low velocity at that time—give it a prism 300 feet wide and 30 feet deep, for instance. Perhaps it would be just as well to secure right of way for this now and construct but part of the prism, though, as a matter of fact, the difference in cost between anything that can be done now and the large prism will not be large." The above from the close of Mr. Johnston's paper does him credit. It is broad and comprehensive and looks into the future. It is to be regretted that some other portions of his paper are not consistent with it.

CLOSURE.

T. T. Johnston—Some readers, if I may judge from the newspaper comments, have found fault with that paragraph of the paper which reads as follows:

"There is no doubt in the writer's mind but that the facts pertaining to the effect of the flow during the past year have been misunderstood, and possibly exaggerated, in the interests represented by the fault-finders." The writer will offer in evidence in this assertion the following leading editorial from the Chicago Record-Herald of April 17th, 1901:

WENTER STATES THE FACTS.

Frank Wenter is one of three drainage trustees who have a correct conception of the meaning of the title. He was on the board when it was very much more respectable than it is to-day, when there was some genuine pride and enthusiasm

> in its work, when a majority of the members felt the glow of public spirit and recognized their public obligations. Amid the present decidedly queer associations, his influence has naturally waned at board meetings, but his testimony on the outside weighs more than that of the majority, and this is what he says of the latest confidence game
>
> "All this talk about reduced flow amounts to nothing. We should have 300,000 cubic feet of water passing through the channel every minute instead of 200,000, as ordered by the War Department. Had nothing been said about this problem there would have been no trouble. Public sentiment was stirred up, however, by some of the trustees themselves, and they have used this question as a club to force the bills now pending at Springfield. That's the whole truth about this matter."
>
> Probably the force of the indictment will not be felt by the guilty parties, but it means—first, that they have betrayed their office in a shameless manner; second, that they have played directly into the hands of the enemies of Chicago, and, third, that their object is what is technically known as a "graft." The object, it seems, is in a fair way to be defeated, but the idiotic gabble about the difficulties of the shipping interests and the sufferings of St. Louis will come back to plague the people if not the board. We shall hear that the trustees themselves said this and that, as if the case were closed by the official evidence, and science and facts will have a harder time because of these treacherous witnesses.
>
> But it must be said for them that they are fufilling prophecy at a great rate.

Perhaps some apology should be made for the introduction of controversy of this character before the Society, and it may be said, by way of explanation, that among other things that characterized the last annual meeting of the Society when this self-same subject was up for discussion, there was a distinct insinuation by some speakers that the improvement of the river, hitherto made by the Sanitary District and well on to completion, involved an engineering mistake. Statements then made have been somewhat modified in the proceedings printed in the Journal, February, 1901, but enough is left to still convey the same insinuation. The writer has been credited with having developed the plans in question, and claims that these plans have accomplished all that was expected of them, viz., allow the continuous flow of 300,000 c. f. m. through the river, and have rendered the river better for navigation than it was previously. This statement cannot be reconciled with the printed proceedings of the annual meeting. At that meeting the velocity of flow in the river was the burden of the talk from an engineering point of view. Not a single reference was made to the radical deepening of the river which has been made, and which has permitted more extended navigation of ships and the carrying of large cargoes where such boats could not possibly go before. Not a mention was made of the fact that the improvements have not been fully completed, and that the troubles of the last year, such as they were, had occurrence, in greater part, at the unimproved places. Nor was any mention made of sundry other benefits that navigation is profiting by. More forcible yet is the fact that no mention was made (except Mr. Braden's allusion to the 39th street sewer) as to the means so easily and early available for further improvement, by executing a trivial work at the Washington street tunnel and the completion of the 39th street conduit.

The talk was all on velocity and all the ills of navigation were attributed to velocity inferentially. The truth is that there were troubles before the velocity was ever introduced, and the writer believes that the sum of the troubles before the increase of the velocities was greater than it has been since. Velocity is certainly a greater or less inconvenience to navigation, but does not by any means constitute the entire measure of the merits of a navigation situation.

The critics may doubtless exempt themselves by denying any intention of making the insinuations in question, and perhaps they did not do so willfully. They have, nevertheless done so, and the matter is spread on the proceedings of the Society, without any opportunity ever having been afforded the writer to reply. He believes this is sufficient apology for submitting the above newspaper clipping. It substantially controverts a remark in the address by Mr. L. E. Cooley, page 2 of February Journal, which reads: "That it (the current) has been to the detriment of commerce is universally conceded," etc. It has a direct bearing on the remarks of Mr. P. B. Weare, in the last paragraph on page 7; also in the remarks of Capt. J. G. Keith, in reference to current, about the middle of page 25.

The writer has read the discussion by Mr. Randolph with much interest. He specially wishes to disavow any intention of attributing to him, or any other member of the Sanitary District engineering force, any of the misrepresentations referred to. He begs to differ with him on some points below mentioned.

Mr. Randolph's first criticism is based on a misprint in the advance copy of paper. The channel involved was, as he says, 200 feet wide by 25 feet deep.

His statement of the average weekly flow through the Chicago river, December 1, 1900, to February 2, 1901, is to the point, in that it fully justifies the writer's intimations that a larger flow was in existence than the river was designed to carry, even when the plans for improvement are fully executed. This table also has a bearing on the remarks of Mr. P. B. Weare, above referred to, wherein Mr. Weare says, as early as January 8th, "they have been asked to shut it off for the reason that it is injuring property at many points in the river." The table does not show that it was shut off, nor does the writer believe any damage of moment was done.

The writer is inclined to believe that the flow was really larger than Mr. Randolph's table indicates, wherein direct issue is taken with the data of the Sanitary District. This disagreement is based on the showing of the dam No. 2 at Joliet. Until all the data are reconciled, there can be no undisputed conclusion as to the real flow in the Chicago river and Drainage Canal. Quite a series of observations will be needed, and it is not understood that they have yet been made in sufficient quantity.

The writer also takes issue with Mr. Randolph as to the loss of depth at the Washington street tunnel, which Mr. Randolph states to have been as much as four (4) tenths of a foot. By this the writer understands him to mean that the water surface at the Washington street tunnel has been observed to be four (4) tenths of a foot below the surface of Lake Michigan. Greater differences of level than this have had existence frequently previous to the opening of the Drainage Canal; for instance, when the lake rises three (3) feet in twenty (20) minutes, at which times it may be more than a foot higher than the level at Washington street, on account of the time limit needed to raise the water at the latter place. The question in controversy is as to the effect of the flow in altering depth at Washington street, a quantity which may not be determinable by direct observation because of the oscillations of the lake wind effects and the like. The writer still believes that the effect of a flow of 300,000 cubic feet per minute is not to lower it more than a tenth or so.

Mr. Randolph's move to remedy the difficulties at Washington street tunnel was not known to the writer. It is certainly in the right direction, as is also his desire to have the 39th street conduit completed.

The writer will conclude with the statement, that if the completion of the 39th street conduit can be accomplished at an early date, and it is entirely feasible to do so, a great benefit can be expeditiously effected. A similar conduit at 18th street, with river improvement from 18th street to Robey street, may well be considered next.

Gen. Wm. Sooy Smith (by letter)—As a contribution to the discussion of the "Chicago River," its conditions, and the necessity of the enlargement of its channel, necessary for the flow through it of the quantity of water prescribed by the drainage act, without producing a rate of current that would be detrimental to navigation, I would suggest the necessity of a capacious harbor as a roadstead and place of anchorage for vessels which might require such accommodation, instead of having them crowded into the channel of the river. This suggestion grows out of the advisability of minimizing the difficulty of towing and handling vessels in a rapid current; but the far more important consideration is the fact that the great and increasing commerce of the port of Chicago absolutely requires a capacious harbor for its accommodation. The out-shore breakwater already constructed by the United States government affords nearly all the protection required for such a harbor, and it can be completed at comparatively small cost, only requiring to be deepened by dredging, which is now being done.

The river furnishes a certain amount of accommodation as a harbor, and it is in valuable as a means of reaching the docks of the city. With the addition of the enlargement proposed and in progress, Chicago will have a harbor commensurate with its needs and importance as the greatest of our lake ports.

Much of the shipping is now going to South Chicago, and much more will go there, and thus relieve to some extent the Chicago river of the duty it is now called upon to perform. The deepening of the harbor will complete the improvement which the Federal government is wisely carrying out on a liberal scale.

CXXV.

THE ART AND CRAFT OF THE MACHINE.

An Address by Frank Lloyd Wright.

Presented March 20, 1901.

It has too long been a matter of popular belief that practical men of affairs, like you, are one thing, and the artist quite another thing; that the engineer and men of business are to create works, and the artist to "trim them up a bit."

Your new bascule bridges and the memorial bridge across the Seine are in evidence as results produced by this cheerful relationship, and fairly typical, I think, of the way in which artist and engineer work together. The engineer designs his bridge, mathematically correct, doubtless (as far as doing the work economically is concerned) turns it over thus to the architect, who hangs a few swags or garlands over its sides, builds a monument or two on it, without relation to the structure, literally puts the architecture on it, so to speak, and during the process there has been neither sympathy nor intelligent co-operation between the machine or the engineer, and the architect or art, each feeling the other very much in the way.

I think also that the engineer, down in his heart of hearts, despises the artistic just a little, and with the swags and garlands in mind he may be justified in fact; for (partly due to him let him bear in mind) the artistic has become too much in the nature of something to be applied from the outside, without integral relation to that to which it is applied.

Art is mightier than this, and there is beginning here in the middle west a movement (it seems a regenerative movement) which is already making itself felt in the ranks of the professional artist and agitating the schools uncomfortably -- a movement to reject this parasitic condition and seek earnestly for a normal regeneration.

It is some of this new serum that I would infuse into your veins to-night, to disabuse your minds of the idea that the present condition of art as most of you come in contact with it, is neither normal or healthy.

Tradition cannot think, and as the engineer is always and everywhere a thinking man, it will be difficult for you to appreciate the fearful slavery to precedent and tradition existing among architects and artists to-day; the abject teaching of the schools; the idea firmly rooted by such great reformers and moral teachers as Morris, Ruskin and Tolstoi, that the machine to which you, gentlemen, are justly related is the enemy of art and craft, therefore of mankind. Their only hope for the future of art lies in fighting the machine and its product.

It will be difficult for you to realize the despairing strength of this pitiful clinging to old ideals, old records of Greek and Roman ways of doing things, which are now unnatural and obsolete—difficult for you, although the results confront you in such striking instances as the parasitic flesh creeping over the bones of the new post-office across the way, devouring millions of hard-earned American dollars in the name of art, to perpetuate a meaningless mask for the edification of future generations. And had you the mind, you might follow into the field of the decorative arts and find the same diseased condition there.

These things are the real tragedies of modern times—the tragedies of peace and prosperity, betrayal of trust where ignorance assumes gigantic responsibility, where errors of judgment pile up indestructible monuments to neglect and error, which generation upon generation cannot live down—not the wreck of the railway train with its appalling loss of life, nor the few hundred lives laid down in Cuba, but the great wasted opportunities of civilization.

In the years which have been devoted in my own life to working out in stubborn materials a feeling for the beautiful, in the vortex of distorted complex conditions, a hope has grown stronger with the experience of each year, amounting now to a gradually deepening conviction that in the machine lies the only future of art and craft—as I believe, a glorious future; that the machine is in fact, the metamorphosis of ancient art and craft; that we are at last face to face with the machine—the modern Sphinx—whose riddle the artist must solve if he would that art live, for his nature holds the key. This plain duty is thus relentlessly marked out for the artist in this, the machine age, although there is involved an adjustment to cherished gods, perplexing and painful in the extreme; the fire of many long-honored ideals shall go down to ashes to reappear, phœnix-like, with new purposes.

The great ethics of the machine are as yet beyond the ken of the artist or student of sociology; but the artist mind may approach the nature of this thing from experience, which has become the commonplace of his field, to suggest, in time to prove, that the machine is capable of carrying to fruition high ideals in art—higher than the world has yet seen!

Disciples of William Morris cling to an antagonistic view. Yet William Morris himself deeply sensed the danger to art of the transforming force whose sign and symbol is the machine, and though of the new art we eagerly seek he sometimes despaired, he quickly renewed his hope. He plainly foresaw that a blank in the fine arts would follow the inevitable abuse of new-found power, and threw himself body and soul into the work of bridging it over by bringing into our lives afresh the beauty of art as she had been, that the new art to come might not have dropped too many stitches, nor have unraveled what would still be useful to her. That he had abundant faith in the new art his every essay will testify.

That he miscalculated the machine does not matter; he did sublime work for it when he pleaded so well for the process of elimination its abuse had made necessary; when he fought the innate vulgarity of theocratic impulse in art as opposed to democratic, and when he preached the gospel of simplicity.

All artists love and honor William Morris. He did the best in his time for art and will live in history as the great socialist, together with Ruskin, the great moralist—a significant fact worth thinking about, that the two great reformers of modern times professed the artist.

The machine these reformers protested, because the sort of luxury which is born of greed had usurped it and made of it a terrible engine of enslavement, deluging the civilized world with a murderous ubiquity, which plainly enough was the damnation of their art and craft. It had not then advanced to the point which now so plainly indicates that it will surely and swiftly, by its own momentum, undo the mischief it has made, and the usurping vulgarians as well. Nor was it so grown as to become apparent to William Morris, the grand democrat, that the machine was the great forerunner of democracy.

The ground plan of this thing is now grown to the point where the artist must take it up. Genius must progressively dominate the work of the contrivance it has created; to lend a useful hand in building afresh the "fairness of the earth."

That the machine has dealt art, in the grand old sense, a deathblow, none will deny. The evidence is too substantial. By art in the grand old sense, I mean art in the sense of structural-tradition, whose craft is fashioned upon the handicraft-ideal, ancient or modern; an art wherein this form and that form as structural parts were laboriously joined in such a way as to beautifully emphasize the manner of the joining; the million and one ways of beautifully satisfying bare structural-necessities, which have come down to us chiefly through the books as "art."

For the purpose of suggesting hastily and threfore crudely wherein the machine has sapped the vitality of this art, let us assume architecture in the old sense as a fitting representative of traditional-art, and printing as a fitting representative of the machine. What printing—the machine—has done for architecture—the fine art—will have been done in measure of time for all art immediately fashioned upon the early handicraft-ideal.

With a masterful hand Victor Hugo, a noble lover and a great student of architecture, traces her fall in "Notre Dame." The prophecy of Frollo, that "The book will kill the edifice," was to me as a boy one of the grandest sad things of the world. After seeking the origin and tracing the growth of architecture in superb fashion, showing how in the middle ages all the intellectual forces of the people converged to one point architecture—he shows how, in the life of that time, whoever was born poet became an architect. All other arts simply obeyed and placed themselves under the discipline of architecture. They were the workmen of the great work. The architect, the poet, the master, summed up in his person the sculpture that carved his façades, painting which illuminated his walls and windows, music which set his bells to pealing and breathed into his organs—there was nothing which was not forced in order to make something of itself in that time, to come and frame itself in the edifice.

Thus down to the time of Gutenberg architecture is the principal writing the universal writing of humanity. In the great granite books begun by the Orient, continued by Greek and Roman antiquity, the middle ages wrote the last page.

So to enunciate here only summarily a process, it would require volumes to develop; down to the fifteenth century the chief register of humanity is architecture.

In the fifteenth century everything changes. Human thought discovers a mode of perpetuating itself, not only more resisting than architecture, more simple and easy. Architecture is dethroned. Gutenberg's letters of lead are about to supersede Orpheus' letters of stone. The book is about to kill the edifice.

Cut the primitive bed of a river abruptly, with a canal hollowed out beneath its level, and the river will desert its bed.

See how architecture now withers away; how little by little it becomes lifeless and bare. How one feels the water sinking, the sap departing, the thought of the times and people withdrawing from it. The chill is almost imperceptible in the fifteenth century, the press is yet weak, and at most draws from architecture a superabundance of life; but with the beginning of the sixteenth century, the malady of architecture is visible. It becomes classic art in a miserable manner; from being indigenous, it becomes Greek and Roman; from being true and modern, it becomes pseudo-classic.

It is this decadence which we call the Renaissance.

It is the setting sun which we mistake for dawn.

It has now no power to hold the other arts; so they emancipate themselves, break the yoke of the architect, and take themselves off, each in its own direction. One would liken it to an empire dismembered at the death of its Alexander, and whose provinces become kingdoms. Sculpture becomes statuary, the image trade becomes painting, the canon becomes music. Hence Raphael, Angelo, and those splendors of the dazzling sixteenth century.

Nevertheless, when the sun of the middle-ages is completely set, architecture grows dim, becomes more and more effaced. The printed book, the gnawing worm of the edifice, sucks and devours it. It is petty, it is poor, it is nothing. Reduced to itself, abandoned by other arts because human thought is abandoning it, it summons bunglers in place of artists. It is miserably perishing.

Meanwhile, what becomes of printing?

All the life, leaving architecture, comes to it. In proportion as architecture ebbs and flows, printing swells and grows. That capital of forces which human thought had been expending in building is hereafter to be expended in books; and architecture, as it was, is dead, irretrievably slain by the printed book; slain because it endures for a shorter time; slain because human thought has found a more simple medium of expression, which costs less in human effort; because human thought has been rendered volatile and indestructible, reaching uniformly and irresistibly the four corners of the earth and for all.

Thenceforth, if architecture rise again, reconstructed, as Hugo prophesies she may begin to do in the latter days of the nineteenth century, she will no longer be mistress; she will be one of the arts, never again *the* art; and printing—the machine—remains the second tower of Babel of the human race.

So the organic process, of which the majestic decline of architecture is only one case in point, has steadily gone on down to the present time, and still goes on, weakening the hold of the artist upon the people, drawing off from his rank poets and scientists until architecture is but a little, poor knowledge of archeology, and the average of art is reduced to the gasping poverty of imitative realism; until the whole letter of tradition, the vast fabric of precedent, in the flesh, which has increasingly confused the art ideal while the machine has been growing to power, is a beautiful corpse from which the spirit has flown. The spirit that has flown is the spirit of the new art, but has failed the modern artist, for he has lost it for hundreds of years in his lust for the *letter*, the beautiful body of art made too available by the machine. So the artist craft wanes. Craft that will not see that human thought is stripping off one form and donning another, and artists are everywhere, whether catering to the leisure class of old England, or ground beneath the heel of commercial abuse here in the great West, the unwilling symptoms of the inevitable, organic nature of the machine, they combat, the hell-smoke of the factories they scorn to understand. And, invincible, triumphant, the machine goes on, gathering force and knitting the material necessities of mankind ever closer into a universal automatic fabric; the engine, the motor and the battleship, the works of art of the century!

The machine is intellect mastering the drudgery of earth that the plastic art may live; that the margin of leisure and strength by which man's life upon the earth can be made beautiful, may immeasurably widen; its function ultimately to emancipate human expression!

It is a universal educator, surely raising the level of human intelligence, so carrying within itself the power to destroy, by its own momentum, the greed which in Morris' time and still in our own time turns it to a deadly engine of enslavement. The only comfort left the poor artist, side-tracked as he is seemingly, is a mean one; the thought that the very selfishness which man's early art idealized, now reduced to its lowest terms, is swiftly and surely destroying itself through the medium of the machine.

The artist's present plight is a sad one; but may he truthfully say that society is less well off because architecture, or even art, as it was, is dead, and printing, or the machine, lives? Every age has done its work, produced its art with the best tools or contrivances it knew, the tools most successful in saving the most precious thing in the world—human effort. Greece used the chattel slave as the essential tool of its art and civilization. This tool we have discarded, and we would refuse the return of Greek art upon the terms of its restoration, because we insist now upon a basis of democracy.

Is it not more likely that the medium of artistic expression itself has broadened and changed until a new definition and new direction must be given the art activity of the future, and that the machine has finally made for the artist, whether he will yet own it or not, a splendid distinction between the art of old and the art to come? A distinction made by the tool which frees human labor, lengthens and broadens the life of the simplest man, thereby the basis of the democracy upon which we insist.

To shed some light upon this distinction, let us take an instance in the field naturally ripened first by the machine—the commercial field. The tall modern office building is the machine pure and simple.

We may sense here an advanced stage of a condition surely entering all art for all time; its already triumphant glare in the deadly struggle taking place here between the machine and the art of structural-tradition reveals "art" torn and hung upon the steel frame of commerce, a forlorn head upon a pike, a solemn warning to architects and artists the world over.

We must walk blindfolded not to see that this magnificent resource of machine and material has broadcast degradation of every type and form sacred to the art of old. It has brought us a pandemonium of tin masks, huddled deformities, and decayed methods; quarreling, lying, and cheating, with hands at each other's throats—or in each other's pockets; and none of the people who do these things, who pay for them or use them, know what they mean, feeling only—when they feel at all—that what is most truly like the past is the safest and therefore the best.

With this mine of industrial wealth at our feet we have no power to use it except to the perversion of our natural resources? A confession of shame which the merciful ignorance of the yet material frame of things mistakes for glorious achievement. We half believe in our artistic greatness ourselves when we toss up a pantheon to the god of money in a night or two, or pile up a mammoth aggregation of Roman monuments, sarcophagi and Greek temples for a post-office in a year or two—the patient retinue of the machine pitching in with terrible effectiveness to consummate this unhallowed ambition—this insult to ancient gods. The delicate, impressionable facilities of terra cotta becoming imitative blocks and voussoirs of tool-marked stone, badgered into all manner of structural gymnastics, or else ignored in vain endeavor to be honest; and granite blocks, cut in the fashion of the followers of Phidias, cunningly arranged about the steel beams and shafts, to look "real"—leaning heavily upon an inner skeleton of steel for support from floor to floor, which strains beneath the "reality." The "Masters"—ergo, the fashionable followers of Phidias—have been trying to make this wily skeleton of steel seem all sorts of "architecture" at once, when the world knows—except the "Masters"—that it is not one of them.

See now, how an element—the vanguard of the new art—has entered here, which the structural art equation cannot satisfy without downright lying and ignoble cheating.

This element is the structural necessity reduced to a skeleton complete in itself without the craftsman's touch. At once the million and one little ways of satisfying this necessity beautifully, coming to us chiefly through the books as the traditional art of building vanish away—become history.

The artist is emancipated to work his will with a rational freedom unknown to the laborious art of structural tradition—no longer tied to the meagre unit of brick arch and stone lintel, nor hampered by the grammatical phrase of their making—but he cannot use his freedom.

His scientific brother has put it to him before he is ready.

The modern tall office building problem is one representative problem of the machine. The only rational solutions it has received in the world may be counted upon the fingers of one hand. The fact that a great portion of our "architects" and "artists" are shocked by them to the point of offense is as valid an objection as that of a child refusing wholesome food because his stomach becomes dyspeptic from over-much unwholesome pastry—albeit he be the cook himself. We may object to the mannerism of these buildings, but we can take no exception to their manner nor hide from their evident truth. The steel frame has been recognized as a legitimate basis for a sincere clothing of plastic material that idealizes its purpose without structural pretense.

This principle has at last been recognized in architecture, and though the "Masters" refuse to accept it as architecture at all, it is a glimmer in a darkened field the first sane word that has been said in art for the machine.

The art of old idealized a structural necessity—now rendered obsolete and unnatural by the machine and accomplished it through man's joy in the labor of his hands. The new will weave for the necessities of mankind, which his machine will have mastered, a robe of ideality no less truthful, but more poetical, with a rational freedom made possible by the machine, beside which the art of old will be as the sweet, plaintive wail of the pipe to the outpouring of full orchestra.

It will clothe necessity with the living flesh of virile imagination.

If the artist will only open his eyes he will see that the machine he dreads has made it possible to wipe out the mass of meaningless torture to which mankind, in the name of the artistic, has been more or less subjected since time began; for that matter, has made possible a cleanly strength, an ideality and a poetic fire that the art of the world has not yet seen; for the machine, the process, now smooths away the necessity for petty structural deceits, soothes this wearisome struggle to make things seem what they are not, and can never be; satisfies the simple term of the modern art equation as the ball of clay in the sculptor's hand yields to his desire—comforting forever this realistic, brain-sick masquerade we are wont to suppose art.

Our modern materials are old materials in more plastic guise, rendered so by the machine, itself creating the very quality needed, in material to satisfy its own art equation.

We have seen in glancing at modern architecture how they fare at the hands of art and craft; divided and subdivided in orderly sequence, with rank and file of obedient retainers awaiting the Master's behest—steel and iron, plastic cement and terra cotta.

Who can sound the possibilities of this old material, burned clay, which the modern machine has rendered as sensitive to the creative brain as a dry plate to the lens a marvelous simplifier? And this plastic covering material, cement, another simplifier, enabling the artist to clothe the structural frame with a simple, modestly beautiful robe, where before he dragged in five different kinds of material to compose one little cottage, prettily arranging it in an aggregation supposed to be picturesque—as a matter of fact, millinery, to be warped and beaten by sun, wind, and rain into a variegated heap of trash.

There is the process of modern casting in metal—one of the perfected offices of the machine, capable of any form to which fluid will flow, to perpetuate the imagery of the delicately poetic mind without let or hindrance within reach of everyone, therefore insulted and outraged by the bungler forcing it to a degraded seat at his degenerate festival. Multitudes of such processes are expectantly awaiting the sympathetic interpretation of the master mind; the galvano-plastic and its electrical brethren, a prolific horde, now cheap fakirs imitating real bronzes and all manner of the antique, secretly damning it in their vitals; electro-glazing, a machine shunned because too cleanly and delicate for the clumsy hand of the traditional designer, who depends upon the mass and blur of leading to conceal his lack of touch; that delicate thing, the lithograph—the prince of a whole province of processes—see what this becomes in the hands of a master like Whistler. He has sounded but one note in the gamut of its possibilities, but that product is intrinsically true to the process, and as delicate as the butterfly's wing. Yet the most this particular minion of the machine did for us, until then in the hands of art and craft, was to give us a cheap, imitative effect of painting.

So spins beyond our ability to follow to-night, a rough thread of evidence that the machine has weakened the artist; all but destroyed his hand-made art, if not its ideal. These evident instances should serve to hint, at least to the thinking mind, that the machine is a marvelous simplifier; the emancipator of the creative mind, and in time the regenerator of the creative conscience. We may see that this destructive process has begun and is taking place that art might awaken to the power of fully developed senses promised by dreams of its childhood, even though that power may not come the way pictured in those dreams.

Now, let us ask ourselves whether the fear of the higher artistic expression demanded by the machine, so thoroughly grounded in the arts and crafts, is founded upon a finely guarded reticence, a recognition of inherent weakness or plain ignorance? Let us, to be just, assume that it is equal parts of all three, and try to imagine an arts and crafts society that may educate itself to prepare to make some good impression upon the machine.

Such a society will, of course, be a society for mutual education.

Exhibitions will not be a feature of its programme for years, for there will be nothing to exhibit except the short-comings of the society, and they will hardly prove either instructive or amusing at this stage. This society must, from the very nature of the proposition, be made up of the people who are in the work—that is, the engineers and the manufacturers—coming into touch with those who assume the practice of the fine arts, and sociological workers whose interests are closely allied with art, as their prophets Morris, Ruskin, and Tolstoi evince, and all those who have as personal graces and accomplishment perfected handicraft, whether fashion old or fashion new.

Without the interest and co-operation of the manufacturers and the engineers, the society could not begin to do its work, for this is the corner-stone of its organization. I suppose the thing would resemble a debating society, or something even less dignified, until some one should suggest that it was time to quit talking and proceed to do something, which in this case would not mean giving an exhibition, but rather excursions to factories and a study of processes in place—that is, the minions of the machine in processes too numerous to mention, at the factories with the men who organize and direct them, but not in the spirit of the idea that these things are all gone wrong, looking for that in them which would most nearly approximate the handicraft ideal; not looking into them with even the thought of handicraft, and not particularly looking for craftsmen, but getting a scientific ground-plan of the process in mind, if possible, with a view to its natural bent.

I will venture to say, from personal observation and some experience, that not one artist in one hundred has taken pains to thus educate himself. I will go further and say what I believe to be true, that not one educational institution in America has as yet attempted to forge the connecting link between science and art by training the artist to his actual tools, or, by a process of nature-study, that develops in him the power of independent thought, fitting him to use them properly, or by training the engineer and manufacturer to the basic truths of artistic expression. The training of the engineer, who has no knowledge of cause and effect beyond his mere technique, is as dangerously incomplete as that of the artist, for there is a connection to be made—a blending at the edges of all this tendency of the machine to specialization, and this blending can be accomplished only by a certain sympathy between the specialists: a common understanding of a common purpose before the art of the machine will rise to its true height. Let us call these preliminaries then, a process by which artists receive information which nine-tenths of them lack concerning the tools they have to work with to-day, for tools to-day are processes and machines where they were once a hammer and a gouge, just as the artist to-day is the leader of an orchestra where before he was star performer: a process by which the engineer receives a broader grasp of the larger ends he is to serve, and develops a sympathy with his brother in the arts.

This proceeding doubtless would be of far more educational value to the artist than to the engineer or manufacturer, at least for some time to come, for there would be a difficult adjustment to make on the part of the artist and an attitude to change. So many artists are chiefly "attitude" that some would undoubtedly disappear with the attitude. But if out of twenty determined students a ray of light should come to one, to light up a single operation, it would have been worth while, for that would be fairly something; while joy in mere handicraft is like that of the man who played the piano for his own amusement—a pleasurable personal accomplishment without real relation to the grim condition confronting us.

Granting that a determined, dauntless body of artist material could be brought together with sufficient persistent enthusiasm to grapple with the machine, would not some one be found who would provide the suitable experimental station (which is what the modern Arts and Crafts shop should be) an experimental station that would represent in miniature the elements of this great pulsating web of the machine, where each pregnant process or significent tool in printing, lithography, galvano-electro processes, wood and steel working machinery, muffles and kilns would have its place, and where the best young scientific blood could mingle with the best and truest artistic inspiration, to sound the depths of these things, to accord them the patient, sympathetic treatment that is their due?

Surely a thing like this would be worth while—to alleviate the insensate numbness of the poor fellows in the harsh, hard shops, who know not why nor understand, whose dutiful obedience is chained to botch work and bungler's ambition; surely this would be a practical means to make their dutiful obedience give us something we can all understand, and that will be as normal to the best of this machine age as a ray of light to the healthy eye; a real help in adjusting the man to a true sense of his importance as a factor in society, though he does tend a machine.

Teach him that the machine is his best friend—will have widened the margin of his leisure until enlightenment shall bring him a further sense of the plan of progress in which he, too, justly plays his significant part.

If the art of the Greek, produced at such cost of human life, was so noble and enduring, what limit dare we now imagine to an art based upon adequate life for the individual?

The machine is for man, not man for the machine!

In due time it will come to him!

Meanwhile, from where are the trained nurses in this industrial hospital to come if not from the modern arts and crafts.

Shelley says a man cannot say—"I will compose poetry." "The greatest poet even cannot say it, for the mind in creation is as a fading coal which some invisible influence, like an inconstant wind, awakens to transitory brightness; this power arises from within like the color of a flower which fades and changes as it is developed, and conscious portions of our nature are unprophetic either of its approach or its departure;" and yet in the arts and crafts the problem is presented as a more or less fixed quantity, highly involved, requiring a surer touch, a more highly disciplined artistic nature to organize it as a work of art.

The original impulses may reach as far inward as those of Shelley's poet, be quite as wayward a matter of pure sentiment, and yet after the thing is done, showing its rational qualities, is limited in completeness only by the capacity of whoever would show them or by the imperfection of the thing itself.

This does not mean that art may be shown to be an exact science.

"It is not pure reason, but it is always reasonable."

It is a matter of perceiving and portraying the harmony of organic tendencies; is originally intuitive because the artist nature is a prophetic gift that may sense these qualities afar.

To me, the artist is he who can truthfully idealize the common sense of these tendencies in his chosen way.

So I feel conception and composition to be simply the essence of refinement in organization, the original impulse of which may be registered by the artist nature as unconsciously as the magnetic needle vibrates to the magnetic law, but which is, in synthesis or analyisis, organically consistent, given the power to see it or not.

And I have come to believe that the world of art, which we are so fond of calling the world outside of science, is not so much outside as it is the very heart quality of this great material growth—as religion is its conscience: a foolish heart and a small conscience.

A foolish heart, palpitating in alarm, mistaking the growing pains of its giantframe for approaching dissolution, and whose sentimentality the lusty body of modern things has outgrown.

Upon this faith in art as the organic heart of the scientific frame of things, I base a belief that we must look to the artist brain, of all brains, to grasp the significance to society of this thing we call the machine, when that brain be not blinded, gagged, and bound by false tradition, the letter of precedent. For this thing we call art is it not as prophetic as a primrose or an oak? Therefore, of the essence of this thing we call the machine, which is no more or less than the principle of organic growth working irresistibly the will of life through the medium of man.

Take the modern elevator to the top of a great down-town office building at nightfall, and you may see how in the image of material man, at once his glory and menace, is this thing we call a city.

There beneath, grown up in a night, is the monster leviathan, stretching acre upon acre into the far distance. High overhead hangs the stagnant pall of its fetid breath, reddened with the light from its myriad eyes endlessly everywhere blinking. Ten thousand acres of cellular tissue, layer upon layer, the city's flesh, outspreads enmeshed by intricate network of veins and arteries, radiating into the gloom, and there with muffled, persistent roar, pulses and circulates as the blood in your veins, the ceaseless beat of the activity to whose necessity it all conforms.

Like the sanitation of the human body, poisonous waste is drawn from the system of this enormous creature; absorbed first by the infinitely ramifying, thread-like ducts gathering at their sensitive terminals matter destructive to its life, hurrying it to millions of small intestines, to be collected in turn by larger, flowing to the great sewer, on to the drainage canal, and finally to the ocean.

This vast acreage of flesh-like tissue is again knit and inter-knit with a nervous system marvelously complete; delicate filaments for hearing, knowing, almost feeling the pulse of its organism, acting upon the ligaments and tendons for motive impulse, in all flowing the impelling fluid of man's own life.

Its nerve ganglia! The peerless Corliss tandems whirling their hundred ton fly-wheels, fed by gigantic rows of water tube boilers burning oil, while beyond, the incessant clicking, dropping, waiting – lifting, waiting, shifting of the governor gear controlling these modern Goliaths, seems a visible brain in intelligent action as it registers infallibly in the enormous magnets, purring in the giant embrace of great induction coils, generating the vital current meeting with instant response in the rolling cars on elevated tracks ten miles away, where the glare of the Bessemer steel converter makes a conflagration of the clouds.

More quietly still, whispering down the long, low rooms of factory buildings buried in the gloom beyond, range on range of stanch, beautifully perfected automatons, murmur contentedly, that would have the American manufacturing industry of five years ago by the throat to-day; manipulating steel as delicately as a mystical shuttle of the modern loom manipulates a silk thread in the shimmering pattern of a dainty gown.

And the heavy breathing, the murmuring, the clangor, and the roar!—how the voice of this monstrous thing, this greatest of the minions of the machine, a great city, rises to proclaim the marvel of the units of its structure;—the ghastly warning boom from the deep throats of vessels heavily seeking inlet to the waterway below, answered by the echoing clangor of the bridge bells growing nearer and more ominous as the vessel cuts momentarily the flow of the nearer artery, warning the current from the swinging bridge now closing on its stately passage, just in time to receive in a rush of steam, as a streak of light, the avalanche of blood and metal hurled across it and gone, roaring into the night on its glittering bands of steel; ever faithfully encircled by the magic lines tick-tapping its invincible protection.

Nearer, in the building ablaze with midnight activity, a wide white band streams into the marvel of the multiple press, receiving unerringly, indelible impression of human hopes, joys, and fears throbbing in the pulse of this great activity as infallibly as the gray matter of the human brain receives the impression of the senses, to come forth millions of neatly folded, perfected news sheets, teeming with vivid appeals to passions, good or evil; weaving a web of intercommunication so far reaching that distance becomes as nothing, the thought of one man in one corner of the earth one day, visible to the naked eye of all men the next; the doings of all the world reflected as in a glass, so marvelously sensitive this simple white band streaming endlessly from day to day becomes in the grasp of the multiple press.

If the pulse of activity in this great city, to which the tremor of the mammoth skeleton beneath our feet is but an awe-inspiring response, is thrilling, what of this prolific, silent obedience?

And the texture of the tissue of this great thing, this forerunner of Democracy, the Machine, has been deposited particle by particle, in blind obedience to organic law, the law to which the great solar universe is but an obedient machine.

Thus is the thing into which the forces of art are to breathe the thrill of ideality! A soul!

DISCUSSION.

Mr. Emil Lorch (of the Art Institute) Mr. Chairman and Gentlemen: I have not the power of expression of Mr. Wright, but there are a few suggestions that occur to me. The first one is this, that in some respects the relation of the architectural schools is not as vital to the architectural profession as that of the engineering schools to the engineering profession; as a consequence, we find that of the two, the engineer has advanced farther in his profession. The engineer dealing with new problems and new materials and processes has quickly adapted himself to these conditions, and honestly and squarely found for them a solution. I think in that sense he has forged far ahead of his brother worker. The majority of our architects cling more or less, and largely because of the methods of the schools in which they are trained, to tradition, and, as Mr. Wright has pointed out, they use forms that were developed to meet conditions different from our own. They too often "adapt" instead of seeking to "create," which latter should be the essential characteristic of the artist; and this must continue until in the architectural schools a better training is given the architect in the fundamental principles of design, not doing, as is now the practice, drilling him to such an extent in the use of traditional forms, in the hope of thus teaching him principles of design and cultivating his taste, that he is seldom afterwards able to think artistically for himself.

It was my fortune to be trained in an architectural school—in fact, I am interested in such a one now,; but I earnestly hope the architectural schools will be able to solve the question of a proper training in design to meet modern conditions.

In this country there is a movement in the direction of broadening our architectural education. I think perhaps one of the greatest impulses has come from the enginering profession, and because the engineer has almost always refused to be constrained by the so-called art of the architect, which to a great extent has not been art at all. One result of this may be seen in the new Alexander bridge in Paris, which Mr. Wright undoubtedly had in mind, and in which there is no vital connection between the decoration and the structural portion itself. The great changes that have come into architecture because of the development of steel construction have been so rapid that the art of the architect has not been able to keep pace with it, and thus has not been able to idealize the new forms which would necessarily arise from a new manner of construction; nor has that art taken advantage for decorative purposes of the plant forms so abundant in this country.

But there is another important thing to be pointed out, and that is the workmen of this country. We are not doing anything for them. On a trip abroad some years ago, partially for the purpose of looking into the systems of art instruction, I found that in Berlin and some of the other German cities they have evening schools for the different classes of workmen. The result is that there the architect finds men able to carry out his ideas. If we could do something of that kind for our workmen, the architect would be more liable to find an artistic working out of his ideas. Our public schools are in a way preparing for that. Drawing and nature study have been more largely introduced in the public schools than ever before, and from such preparatory schooling must come a different class of men. Perhaps we may also hope that some of the engineers will come out of the same ranks and will therefore construct with more sympathy.

Let us hope that these new methods of education will result in a better art expression, employing the machine as a tool; but, of course, what the result will be is a thing for the future to solve.

Those, however, are the points I had in mind—the education of the workmen themselves, the possibilities of the public school system, and the relation between the architectural schools and the actual conditions.

Perhaps the new architectural school will more closely unite the scientific and the practically artistic. By this I mean that there will be a much closer relation for architectural students between the schools of engineering and those of painting, sculpture and decorative design. These should unite more closely, and through such a union will perhaps spring up something that will be artistic in a purely American sense, and therein I am sure even the architect will admit that the engineer and the machine will have one of the very most important parts to play.

Prof. P. M. Chamberlain (Lewis Institute)—I think that one of the difficulties that not only the engineers, but perhaps all humanity labors under, is the fact that beauty is not an intrinsic or absolute quality. It is a relative quality or matter of taste apparently. It is difficult to say why the straight line may not be as beautiful as the curved line, or a combination of straight lines forming geometric figures may not be as beautiful as a combination of curved lines and straight lines or ellipses, etc. You will readily see from my language that I am not educated in art. It seems to me that there is one point that we can look at fairly and squarely: that beauty, or that which appeals to us as being beautiful, is largely a training of the eye or of the mind, or of the two combined. For example, we have gotten accustomed to seeing in ancient structures beautiful arches which are appropriate to the material used; but when we see the modern bridge which has no curves, it does not favorably appeal to us at first sight as it does eventually. We get used to these ugly things, and finally they take on an appearance of beauty. Pope evidently had this in mind when he wrote:

> "Vice is a monster of so frightful a mien,
> As to be hated needs but to be seen;
> Yet seen too oft, familiar with her face,
> We first endure, then pity, then embrace "

CXXVI.

ETHICS OF THE ENGINEERING PROFESSION.*

By Victor C. Alderson, Dean of Armour Institute of Technology.

The work of the professional man, be he doctor, lawyer, clergyman or engineer, always bears some direct relation to well-defined fundamental principles. These principles may result from the experience of humanity, they may come from *a priori* reasoning, or they may rest upon combinations of these two. But no profession can be regarded as stable until it has such a body of well-established principles as will guide a member of the profession in determining the actual value of his work, will teach him that his calling is honorable to himself and valuable to the community, and will determine what line of action may elevate the profession and instill into him the lesson that he must do nothing to bring reproach upon his chosen profession. In a word, they give him ideals to struggle for, and to struggle for an ideal is the only method of gaining true and lasting satisfaction. Pure professional success, as distinguished from mere money getting, depends upon acting in harmony with these principles.

A trade may be distinguished from a profession in that it does not recognize the importance of these basal principles. Not that the man at the bench, the machine, or the loom does not need guiding principles in his work, but that they assume a distinctly subordinate place. The professional man must be a broader man, must have a wider grasp of relations, must have the ability to solve new complications, must be the leader and the thinker as well as the doer. The machinist may run his machine, but the mechanical engineer understands machinery. The electrician may close the circuit, but the electrical engineer understands polyphase machinery. The engine man may open the throttle, but the railway engineer understands railroading. The engineer, whatever his specialty may be, must base his practice upon the well-established laws of nature. If he belongs to the group of the successful rather than the unsuccessful engineers, he must have plain, practical sense, a scientific education, tact, business ability and a strong personality.

The principles which underlie the legal profession, no matter what the lawyer may regard as professional ethics in a particular case, are statutes and the common law—that is, crystallized human experience. These laws form the principles upon which he aims to decide between right and wrong, between justice and injustice, and his work, except in certain criminal cases where the facts of guilt alone are to be proved, consists largely in properly fitting each new case under some one of the numerous general cases. The two parties to a suit merely urge the application of different principles, and the ultimate reason for legal wrangles is that the fundamental principles, according to which judgment is formed, are of purely human origin; consequently, they are in a state of change, of evolution. For this reason the determination of right and wrong is difficult; the question is always debatable; the legal profession has no solid foundation on which to rest its basal principles. The witty retort of the lawyer makes my meaning clear. "That is not the law," said the judge, in answer to a claim set up by a lawyer. "It was, sir, until your Honor spoke," replied the lawyer.

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At first thought the clergyman seems to have an advantage over the lawyer. To him, "Thus saith the Lord," in Scripture is as potent as the laws of the Lord in nature. However, he will admit that the element of faith must enter every religious creed, and that without faith his creed would not be religious. Rev. James Freeman Clarke would never have found the materials for his "Ten Great Religions" were this not true. But the quality and quantity of faith varies with peoples to such an extent that many religious sects, violently opposed to each other, have resulted. It is true, however, that their common ground is ethical or moral; that is, their unifying principle is based on human standards and, therefore, is debatable. Consequently, the profession does not have that unfailing criterion which we are seeking.

The medical profession has a more favorable position. The physician seeks to aid nature. He can do but little more, and he is ever trying to find out just how nature will work in the particular case under consideration. He deals with organic nature, and, while he may endeavor to be strictly scientific, the complications are so great that he cannot predict the result with certainty. So many variable elements affect his diagnosis that he has no exact criterion for judgment. He is very largely a mere observer of nature's workings. Like the lawyer and the minister, his standards of right and wrong are based, though in a less degree, upon shifting human experience and observation. In all these cases there seems to be lacking an incontrovertible, unfailing criterion by which the professional man's work can be judged.

In the case of the engineer the circumstances are quite different. The relation between the engineer on the one hand, and the laws of nature on the other, is unique, and differs from the relation that exists between any other professional man and nature. Unlike the geologist, who is limited in his observations to those favorable localities which nature has been kind enough to unfold for his inspection, or the biologist, who must stand merely as an obsever of nature's acts, the engineer pins nature down and forces her to answer his question. It may be only a yes or no, but it is an answer, and since he can vary his questions that is, the conditions of his experiment—he can ultimately get the information he desires. He deals with the immutable, the unchanging laws of inorganic nature. He, alone of all professional men, has an unvarying criterion by which he may decide the right and the wrong, the correct and the false. He gets accurate data by which he may build his bridge, construct his dynamo, or lay out his railroad. Departure from these data means failure. Other professional men are subject to varying human laws and human notions, and so get along without ever having before them an absolute standard; but the engineer is forced to be in harmony with natural laws; his work must be absolutely truthful; his logic must be without flaw. Sophistry and ignorance are not for him. He must know, and know accurately; he must reason, and reason logically. If he does not know the stresses in his bridge, the endurance of his material, or the details of his dynamo, he cannot rank as an engineer. Nature, calm and dispassionate, is always on guard over him. No other man in the world, I believe, unless it is the chemist or physicist, is subject to such rigid and unceasing discipline; no man's errors are so glaringly brought to light as his. The lawyer can fall back on the plea that the judge was biased, or the jury packed; the doctor may, perchance, bury his mistakes; but the mistakes of the engineer bury him. We accept his success as natural, because it is in harmony wiih nature's laws; his errors are glaring, because they are out of harmony with nature. All the world sees his failures. A mere tyro can recognize a poor roadbed, defective machinery or a dangerous bridge. The engineer has, then, for his ethics the most dignified and exalted standard; he has an absolute and unvarying criterion for truth and error; he has over him a judge who will decide with unerring swiftness that his work is a failure if he violates the law. We have found, then, the ultimate lines of distinction between the engineering profession and all other professions.

Recognizing, therefore, that the success of the engineer's work rests upon harmony with nature's laws, and that she is merciless in showing his weakness, that this is the most accurate standard of which we know, we can draw some deductions from these principles and see what effect such a standard has upon the profession as a whole, and upon the mind and character of the individuals. Who is the final arbiter of professional eminence? In the case of the lawyer, the doctor and the minister, reputation is made and success determined by the public at large—by clients who know, as a rule, little of real professional worth. Since the ultimate standards of judgment rest on human models, quackery is possible and all too common. In the case of medicine and law, legislation defines who shall practice, but the requirements are far too low. Legislation, however, recognizes no such profession as engineering, consequently the burden of maintaining professional standing rests solely upon the profession itself. Presumably, then, quackery should be more common; but the facts show that it is less common in engineering than elsewhere, for this reason—the final judgment of the success of the lawyer, the doctor or the minister rests with his clients, while in the case of the engineer judgment is rendered by his peers. In no other profession is this judgment so pronounced, in no other profession is quackery so quickly discovered and held up to criticism. As a result, the engineering profession is the best educated for its work of any of the professions. True, there may not be so many stars of the first magnitude in the engineering firmament, but more emit a strong, steady light, and very few show a false light. From the nature of his work the engineer does not have an opportunity to pose before the public; he cannot be the idol of the forum. His success or failure is determined by the judgment of a most competent board of critics—his professional associates.

The distinction which an engineer most covets, and which gives him unquestioned professional standing, is membership in the national engineering societies. This is obtained only after successful professional practice, and is granted by engineers themselves. No other profession demands so high a qualification for membership. In England, membership in the engineering societies takes the place of the engineering degree. In the matter of a professional degree, the engineering profession takes a lofty position. The mere fact that a man has acquired the degree of C. E., M. E., or E. E., counts for little with engineers; less than the M. D. with doctors or the LL. B. with lawyers. If obtained from a high grade institution, it gives a presumption in favor of the holder, but in no case does it carry much weight. The engineering profession is chary of its favors and degrees; it holds that three qualifications are essential to an engineer—natural aptitude, proper technical training and successful experience. No young man, however great his ability or how thorough his training, is an engineer until he has had experience. High as these standards are, they are no higher than we should expect from a profession which has such fundamental tenets.

Every field of activity in the whole realm of nature may yield something of value to the engineer. His interests are world-wide. As man has climbed slowly up the rugged pathway we call civilization, he has needed more and more the services of the engineer. What was yesterday a theory becomes a demonstration to-day, and to-morrow we expect the engineer to apply it for our comfort or convenience. As agencies for civilization, engineering works have been given far too little prominence. True it is that Greece has left us a priceless heritage of art and Rome a code of laws; but in the wake of the Roman armies went the engineer, building bridges, roads and aqueducts, making civilization more advanced. To-day, thanks to our railway experts, the world is smaller than ever before, and is steadily growing smaller; for distance is no longer computed in miles, but in length of time in transit. Once New York and Liverpool were three months apart, now less than a week. With the aid of bridges like the St. Louis, the Brooklyn and the Forth; tunnels like the Mersey, the Sarnia and the St. Gothard; canals like the Manchester and the Suez; trains like the Limited and the Empire State Express, the engineer has done noble work for advancing civilization by making intercommunication easier and removing that ever-recurring obstacle—ignorance of other peoples. The influx of people to the large centers of population has brought forward new problems, not only of travel, but of pure water supply, disposal of sewage, public health, all of which the engineer is called upon to solve. Industrial history may be dry reading, because it does not fire the ardor with thrilling deeds on the field of battle. Some enthusiasm may be kindled over the success of Robert Fulton with his steam engine and Edison with his phonograph, but little or none over the success of John A. Roebling in building the Brooklyn Bridge, or the struggle of our civil engineers to make our present railway travel fast and safe. But to the engineering profession as a whole we must grant the credit for being the greatest practical civilizing agent we have.

From the principles underlying the profession only one conclusion can be drawn as to what are the professional ethics of the engineer. Whether the relation is with the employer, the client or the public, the ideals of the profession are high and well maintained. Men in other callings get wide experience, great learning and national reputations. Their opinions are sought after, and they frequently get into the dangerous condition of thinking that their opinions are of weight merely because they are their own opinions. The engineer, however, is daily and hourly trained by nature to know that his opinions are worthless unless they are carefully deduced from authentic data. Naturally, then, we get sounder and more mature judgment from engineers than from any other class of men; we find less conceit in them, and more straight thinking from accurate data to logical results. Like other professional men, the engineer has his clients whose interests are his own. Honor and duty, therefore, are essential to his success, and become so much a part of his professional equipment that he does not talk about them. The reputable engineer takes for granted that he must love truth and truth only; that he must have a direct purpose; that he must be devoted to his work, and that he must be guided only by the loftiest standards of conduct. All this comes from the exacting requirements which nature puts upon him. Consider the responsibility attached to the engineering profession. In matters religious a man selects his own church, his own minister; in time of sickness he chooses the physician who shall attend him; should he be sued, he selects a lawyer to defend him; but if he rides on a railroad train, does he select the superintendent of motive power, by means of whose professional skill his journey is made in safety? Are the future users of the new East River Bridge, between New York and Brooklyn, consulted in the selection of the civil engineers who are to construct the bridge? The trust which the public has in the engineering profession places upon it a heavy obligation—greater than upon any other profession. For this reason the engineer does not rely upon superficial observations. It is a peculiar trait of human nature that the wish is father to the thought. If, then, observations prove to be as we wish them, we are not apt to be critical; but if they give undesired results, we examine them again with great care. The true engineer is as cautious with favorable as unfavorable data. If he is called upon to make a report, he should make it with the utmost frankness, even though it may displease a client. A proper regard for his own professional standing and the dignity of the profession at large demands that the engineer should hide nothing from his client; doubts as well as favorable facts alike should be submitted. Honesty and truth, then, follow as a natural consequence of his ideals. He need not make special effort to be truthful, for his work follows so closely upon the truths of nature that departure means failure. Every hour and every minute he is trained to truth and honesty. They form an ingredient of his daily tasks, and, unconsciously to him, influence his character. The unchangeable laws under which he works, and which he must rigorously apply, exert a constantly elevating influence upon him. His work is to control, to resist, or to guide the forces of nature. If his data are correct and his reasoning is sound, his finished work stands as permanent evidence of the fact; but if his data are incorrect or his reasoning is faulty, the merciless laws of nature will discover and lay bare to every observer his own incompetence. These very qualities of mind and character which caused him to choose the engineering profession, and which make his work a pleasure, combine to bring his entire work into harmony with the laws of the universe. If his mind and character are not thus attuned, if he is not guided by strict adherence to facts and logical deductions from them, and his ethics are not in harmony with right doing and clear thinking, then he is to that extent not skilled in the application of the forces of nature to the uses of man, and is not an engineer.

Extravagance is a fault of which no true engineer is guilty. One of the greatest claims the engineering profession has upon the respect of the public is that it works constantly and persistently to increase efficiency, to reduce cost, to convert what is harmful or useless into sources of wealth, and to avoid waste. Numerous are the examples which might be cited to maintain this assertion, but they are needless.

One other consideration which results from fundamental principles should be noticed, even though it is purely intellectual. The psychologist recognizes the faculty of constructive imagination, which is not merely the reproduction of images previously obtained; but the rearrangement of these in new forms, adapted to new purposes. This is the intellectual work of the engineer when he designs a new engine. His drawings are but the language by which he communicates his ideas to the workman; they embody the object in every detail which he has mentally formed by his power of constructive imagination. The man who does not possess this intellectual faculty can never be a successful engineer.

In conclusion, I am willing to grant, that in the minds of many laymen, engineering is not regarded as a profession, but as a refined trade or a business; yet I am confident, that if the advocate of engineering as a profession is given a fair hearing, he can easily prove his case. I have claimed that the effect of the engineer's work upon civilization has been very great—greater than most persons realize; but the claim must be made upon the reason rather than upon the feelings, and consequently is more slowly granted; but calm, dispassionate historians will place the credit where it justly belongs. The effect upon the mind and character of the individual engineer, due to the principles which underlie the profession, cannot be easily estimated; but I am confident that if the lives of our prominent engineers could be unfolded to the public gaze, they would show in abundance those qualities of honor, honesty, integrity and manliness which naturally follow from intimate association with nature's inexorable laws.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

D. Van Nostrand Co., New York, N. Y., 1 book, cloth, Water Works Distribution, Laying Out Water Mains, etc., by J. A. McPherson, A. M. Inst. C. E.

Prof. W. D. Pence, Purdue University, Lafayette, Ind., 1 book, cloth, Surveying Manual for Students.

J. W. Crawford, Sec'y Water Board, 9 pamphlets, Annual Reports Lowell (Mass.) Water Board, 1892-1900.

Glen Brown, Sec'y and Editor, American Institute of Architects, 1 pamphlet, Proceedings 34th Annual Convention, Dec., 1900.

U. S. Government Printing Office, Department of Agriculture, 1 pamphlet, Report on A Forest Working Plan (Forestry), Township 40, New York State Forest Preservation.

New England Cotton Manufacturers' Assoc'n, Boston, 1 vol., boards, 334 pages, Transactions, 1901.

E. A. Rossiter, Chicago, 1 pamphlet, Report of the Department of Track Elevation, 1900, City of Chicago.

City of Chicago, 1 vol., cloth, Annual Report, Department of Public Works, 1900.

Wm. H. Blauvelt, Syracuse, N. Y., 2 pamphlets, Description of Plant of Semet-Solvay By-product Coke Ovens at Ensley, Ala., and at Wheeling, W. Va.

City of Chicago, Municipal Librarian, 3 pamphlets, Statistics, Vol. I, Nos. 1, 2 & 3.

S. P. Langley, Sec'y, Smithsonian Institution, Washington, D. C., 1 vol., cloth, Report to Board of Regents, 1899.

Institution of Junior Engineers, London, 1 vol., cloth, Record of Transactions, Vol. X, 1899-1900.

Lowell Water Board, Mass., 9 vols., paper, Annual Reports 1892 to 1900 inclusive.

Geo. F. Stone, Sec'y, Board of Trade, Chicago, 1 vol., paper, 37th Annual Report, 1894.

" " " " Board of Trade, Chicago, 1 vol., cloth, 43rd Annual Report, 1900.

Open Court Publishing Co., Chicago:

    4 numbers (1 vol. XI), paper, The Monist, 1900-1901.
    1 vol., cloth, Popular Scientific Lectures by E. Mach.
    1 " " A Brief History of Mathematics, by Dr. Karl Fink.
    1 vol., cloth, Essays on Number, by Richard Dedekind.
    1 " " Mathematical Essays and Recreations, by Hermann Schubert.

C. H. Crantz, Illinois State Geologist, 10 pamphlets, Bulletins Nos. 3 to 12 inclusive, Illinois State Museum of Natural History.

Armour Institute of Technology, 1 pamphlet, Year Book, 1901-1902.

G. Pavie, Gen'l Sec'y, Compte Rendu des Travaux du Congrés, Paris, 1 vol., cloth, 1901, International Navigation Congress.

C. W. Marx, Professor Mechanical Engineering, Missouri State University, 1 pamphlet, Report on Heating Value and Analysis Missouri Coals.

Spon & Chamberlain, New York City, 1 book, cloth, The Chemistry of Fire and Fire Prevention, by Herbert Ingle.

American Institute of Electrical Engineers, Vol. XVII, pamphlet, Transactions for 1900.

John Crerar Library, 1 pamphlet, Sixth Annual Report, 1900.

Sanitary District of Chicago, 1 vol., cloth and leather, Proceedings Board of Trustees, 1899.

E. E. R. Tratman, Chicago:

1 vol. cloth, Test of Metals, etc., 1899.

1 " " Commercial Relations of the United States, 1900.

1 pamphlet, Commonwealth of Massachusetts, Relations between Cities and Towns and Street Railway Companies.

McGill College and University, Montreal, 1 pamphlet, Calendar, 1901-1902.

Commissioner of Patents, Washington, D. C., 1 vol., paper, Annual Report for 1900.

Rudolph Link, Associate M. W. S. E. (Keuffel & Esser Co.), 3 vols., cloth, "The Compass," Vols. I, II, III.

Geo. Joseph Bell, Bridge Master, Carlisle, Cumberland Co., England, 1 vol., cloth, "A Practical Treatise on Segmental and Elliptical, Oblique or Skew Arches." (Spon & Chamberlain, New York.)

Gates Iron Works, Chicago, 1 vol., leather, Catalogue of Machinery.

Inspector General Navigation and Ports, Ministry of Public Works, 1 pamphlet, paper, Bulletin of Public Works, Buenos Aires, S. A.

Board of Public Works, Grand Rapids, Mich., 1 pamphlet, 28th Annual Report.

Bureau of Foreign Commerce, Commercial Relations of the United States, Vols. I and II, 1899; Vols. I and II, 1890.

" " " pamphlet, Special Consular Reports; Vol. XII, 1899, Highways of Commerce.

" " " pamphlet, Special Consular Report, 1899; Vol. XVII, Disposal of Sewage and Garbage in Foreign Countries.

" " " pamphlet, Special Consular Reports, Vol. III, 1891, Streets and Highways in Europe.

Holly Mfg. Co., Lockport, New York, 3 pamphlets, Catalogues of Pumping Machinery.

BOOK NOTES.

Surveying Manual. A Manual of Field and Office Methods, for the use of Students in Surveying. By William D. Pence, Professor of Civil Engineering, Purdue University, and Milo S. Ketchum, Assistant Professor of Civil Engineering, University of Illinois. Published by the authors. Cloth, pocket size, 4½x6½, 232 pages. Price, $2.00.

The object of the authors, as stated in the preface, is first, "to provide a simple and comprehensive text, designed to anticipate, rather than replace, the usual elaborate treatise; second, to bring the student into immediate familiarity with approved surveying methods ; third, to cultivate the student's skill in the rare art of keeping good field notes and making reliable calculations."

In this the authors have succeeded admirably. As a pocket guide to field practice for students, probably nothing better has been produced. Especially are the instructions in regard to keeping of field notes to be commended. Many engineers have found that it has taken years of practice to attain this art, so generally neglected in the work of engineering schools.

The book contains eleven chapters :

Chapter I, general instructions, gives much good advice to the student in regard to field notes, care of instruments, general decorum and the integrity of his work.

Chapters II to V take up the chain and tape, the compass, the level and the transit. A description of the instrument, its uses, construction and methods of adjustment are given clearly and briefly, with good illustrations, and each chapter ends with a large number of problems to be done in the field or office. A prescribed form of field notes, with liberal sketches, is given. The use of the Engineering News style of freehand lettering is required in the notes, a practice which gives uniformity and clearness and is valuable in drafting.

The illustrations of field notes are a unique and valuable feature, showing an exact representation of the note book page, ruling, lettering, sketches, etc., complete.

Topographic surveying, land surveying and railroad surveying are the headings of the next three chapters. The topographic methods by transit and stadia, plane table and stadia, are given. The sextant is briefly discussed. Land surveying is clearly treated. The subject of railroad surveying is quite fully discussed for a work of its size.

The organization and work of transit, level, and topography parties and other parties on railroad work are given fully, and the office work described in some detail.

The method by transit and stadia, which would be very useful in topographic work if properly used on railroad surveys, might have been mentioned here.

In the last three chapters we find a good discussion of errors of surveying, some valuable time-saving methods of computation, and some plates teaching the freehand lettering prescribed for field notes.

There is no index, but a good table of contents with page references, and each page heading gives the subject there treated.

Though intended primarily for the student in surveying, the book might well be read by any engineer who wishes to use up-to-date methods. It is especially valuable to the young engineer who may have been denied in some degree the advantage of a full course of study of his profession. E. T. E.

Municipal Public Works. An Elementary Manual of Municipal Engineering. By Ernest McCullough, C. E. 1900. Pages 153, with index.

This interesting pamphlet discusses in an informal manner Municipal Engineering as applied to cities of moderate size, with examples drawn from the author's experience on the Pacific Coast.

There are seven chapters in all, the first three of which treat of such matters as are generally considered as coming directly within the province of the city engineer, viz., street grades and pavements; drainage and sewerage, and water supply. The fourth chapter covers street lighting and fire protection, while the last three are devoted to a discussion of the general policies and methods which should prevail in the conduct of city work, together with some remarks on municipal ownership of public facilities. On each of these topics the author has definite and clean cut opinions, based on personal experience, and whether the reader can agree on every point or not, he will find abundant field for thought in many of the suggestions made. The scope of the little work does not, however, permit any extended or strictly technical discussion, so that it is more specially intended for the lay reader rather than for the author's professional brethren. The engineering profession will, however, be glad to hear that the author has in preparation a more extended work, covering the field of municipal engineering in an exhaustive manner, as our literature on the subject is at present comparatively meagre. H. G.

Water Works Distribution. A Practical Guide to the Layout of Systems of Distributing Mains for the Supply of Water to Cities and Towns. By J. A. McPherson, A. M. Inst. C. E. 151 pages, including index, and with diagrams, illustrations and a large folding chart; $5\frac{3}{4}$ x 8 in., cloth bound. Price, $2.50. D. Van Nostrand Co., New York.

The author, whose long connection with water works systems entitles him to speak with authority, gives in this little volume a clear and concise explanation of the proper methods to be pursued in laying out a distribution system. An example district or city is assumed, requiring a low surface reservoir and a high service tower with necessary pumps. The successive steps to be taken to lay out a satisfactory pipe system, showing the proper distribution of valves, hydrants, etc., are clearly set forth at length, necessary formulæ and rules being given.

Explanations and illustrations are given of distinctive pipes, valves and various fittings considered necessary in a first-class distribution system.

One chapter is devoted to meters and the measurement of water, showing also regulating and recording apparatus.

The Deacon waste water meter, used generally in England and in some parts of this country for the detection and prevention of waste in distribution systems, is described and illustrated.

The work is of English origin, and on this account there are variations from our practice in some of the fittings described, sizes of pipes to be used, etc.; but to an engineer in general practice, who may be called upon to consider the question of a water works system for some municipality, this book would refresh his memory on many points, and probably give him some valuable hints relating to such work. S.

The Chemistry of Fire and Fire Prevention. A Handbook for Insurance Surveyors, Works Managers and all interested in Fire Risks and their Diminution. By Herbert Ingle and Harry Ingle. New York: Spon & Chamberlain, 1900. 12 mo, 287 pages, 45 illustrations, tables and index. Price, $2.50.

This handy little book, though written praticularly in the interest of fire insurance, contains much of value to the engineer. Engineering relates not only to the creation of structures, but also their preservation from destruction, whether by fire or otherwise. Some of the book, relating to the chemistry of the subject, may seem to be very elementary, yet it is not out of place, as making more clear the action of combustion. This applies particularly to many steps in manufacturing operations. Many of these operations are described sufficiently full as to make the reading of interest, as explaining the technology of the operations, as well as showing when comes in the risks of fire. The action of oxygen (usually from the atmosphere) in combustion is clearly shown in the chapter on oxygen, and this is as a preliminary to the exposition of combustion, "spontaneous" or otherwise, which means fire risks.

Other chapters relate to coal gas, fuel, illuminants, explosives, oils, volatile solvents and coal tar products, paint and varnish making, textile manufactures, and finally fire prevention and extinction.

In describing the technology of many of the processes of manufacture, the oxidation of one or another substance with a consequent elevation of temperature is clearly shown, this indicating the risks of fire, and consequently what precautions should be taken to guard against disaster. The chapters on oils, and technical applications of them, on volatile solvents and paints and varnishes, contain much condensed information that should be of interest to most engineers. There are numerous foot-notes giving reference to the authorities and sources of information.

Altogether, the book is to be recommended to our engineers as tending to broaden their knowledge and general intelligence. W.

The Management of Engineering Work-Shops. By Arthur H. Barker. A course of six lectures delivered before the Institution of Junior Engineers of London, England.

These lectures, with their discussions, were delivered in February, March and April, 1901, and are well worth the careful attention of what our English cousins would call works managers.

The especial need of these lectures seems to have arisen from the competition of American (that is, United States) shops and factories in the introduction of their wares in markets hitherto held as their own by British establishments.

The author draws a distinction between engineering works and manufactories, and shows how the low cost of many lines of manufacture in this country, notwithstanding a much higher rate of wages, is due to a somewhat lower cost of the raw material, but mostly from the shop methods followed, which results in a larger output per man employed, or per dollar expended in wages. But the lectures contain many hints as to how reforms may be instituted in our shops as well as those in England, which would tend toward cheapening the cost of the output

There are some good suggestions in the lectures, and in the discussion following them, as to keeping cost accounts of work executed; how should these cost accounts be kept, and to the actual cost of any piece of work for material and labor; and what amount should be added to cover the cost of the establishment, the office expenses. There is much variation in practice in this particular, as shown in the discussions, and almost every establishment will have to settle this point for its own practice; yet a careful reading of these lectures and the discussion would doubtless give some valuable hints to the managers of works to help lessen the total cost of the article made for sale, and consequently of profit to the owners of the works. W.

Groves and Thorp's Chemical Technology; or, Chemistry in Its Applications to Arts and Manufactures. Vol. III Gas Lighting. By Chas. Hunt. Philadelphia: P. Blakiston's Son & Co. Large 8vo, cloth, pp. 312 including index and with nearly 300 illustrations. Price $3.50.

The Chemical Technology of Groves and Thorp is well known and has been before the public for some years, and is a mine of valuable information for the student or technist. Vol. I treats of fuels and its application. Vol. II treats of lighting by candles, oils, lamps, etc.

This present volume relates to gas lighting, and the author, as manager of the Burningham gas works, is well qualified for the preparation of this book, which treats of the object in a broad and comprehensive manner.

There is an introductory chapter on the history of gas manufacture, and when one considers the money invested in this industry, the wide dispersion of its manufactures, the relation between modern social and industrial life, and the convenience, almost necessity, of this method of illumination, one marvels that gas lighting as an art is less than a century old. The first portion of this book treats of the early history of this subject, describes by aid of a large plate the various steps in the process, the qualities of gas coal, with tables of analysis, the results of heating the coal or of its destructive distillation, the carbonizaton as it is termed, with the results depending on the temperature employed. Other chapters describe the retorts used, shape, dimensions, composition, setting in the furnaces, including some of the modern regenerative furnaces, planned to save heat The charging of the retorts is considered, with the economy following the introduction of machinery for this purpose.

Following this are chapters describing the adjuncts to the retorts, for the collection, condensation, washing, purifying and storage of the manufactured gas, which is then ready to be distributed to the consumers.

The removal and utilization of the by-products the ammonia and cyanogen compounds, and the purification of the gas—is fully described and with many illustrations, and as a natural sequence follows a chapter on the analysis of the gas before and after purification, which, however, does not include photometry.

The measurement, storage and distribution through the community follows and is fully treated with many illustrations. The next part of the book describes the enrichment of the gas, the manufacture of water gas and its addition to coal gas.

The latter part of the book is devoted to the subject of combustion, gas burners, etc., whether for large assembly rooms, street lighting, or otherwise, and includes a dozen pages on incandescent gas lighting, such as the Welsbach burner and mantle, and others.

The book being written by an Englishman, and with English practice about him, probably neglects mention of some of the newer processes as used in this country; but, taken all in all, the work is a reliable and modern one and worthy of commendation. W.

Popular Scientific Lectures. By Dr. Ernst Mack, of the University of Vienna. Translated by Thos. J. McCormack. The Open Court Publishing Co., Chicago. 12mo, cloth, 382 pages, indexed, 50 cuts. Price, $1.00.

These charming lectures are "A Portrayal of the Spirit and Methods of Science," and embrace such subjects as "The Forms of Liquids," "The Fibers of Corti," "On the Causes of Harmony," "On the Velocity of Light," "Why has a Man two Eyes," "On Symmetry," "On the Fundamental Concepts of Static Electricity," "On the Principle of the Conservation of Energy," "On the Economical Nature of Physical Inquiry," "On Transformation and Adaptation in Scientific Thought," On the Principle of Comparison in Physics," "On the Part Played by Accident in Invention and Discovery," On Sensations of Orientation," "On Instruction in the Classics and the Mathematico-Physical Sciences," etc.

One or another or all of these lectures could be read with profit and interest by engineers, and unless he be very well read they will furnish him with some new and wide-reaching ideas for future consideration. The author has a fine sense of humor, coupled with a delicate play of fancy. The spirit of the author has been admirably preserved by the translator. By the appropriate choice of matter, with suitable illustrations, the charm and poetry of research is conveyed to the reader. These lectures extend over considerable length of time, extending from 1864 to 1897, and treat of phenomena in which all should be interested in a delightful style and with wonderful clearness. They give a remarkable insight into the relationship between the various fields of inquiry cultivated under the name of physics. Some of the most recondite problems of natural science are treated in so charmingly untechnical a manner, and with such a wealth of illustration, that persons of even ordinary intelligence and education should have little difficulty in comprehending them. The style is admirable and the whole volume seems gloriously alive and human. W.

Essays on the Theory of Numbers: I. Continuity and Irrational Numbers. II. The Nature and Meaning of Numbers. By Richard Dedekind. Translated from the German by Prof. Beman of the University of Michigan. Chicago: The Open Court Publishing Co. 115 pp., cloth. 75c.

The author of these interesting essays states that while he was lecturing on the elements of the differential calculus the lack of any really scientific foundation for arithmetic became strikingly evident.

As language came first and grammar afterwards, so numbers were notions and were manipulated in various ways, bringing forth correct results long before an attempt was made to scientifically analyze all their properties and governing laws.

This it appears, as is frequently the case, that the contemplation of the most advanced development of a science is requisite for the ability to make satisfactory analysis of its simplest forms.

The discussion of continuity and irrational numbers forms the first portion of the work and these are treated very exhaustively.

The author affirms that the differential calculus, though dealing with continuous magnitude, does not explain this continuity, as proofs are based on geometric notions or those suggested by geometry, or they depend upon theorems which are never established in a purely arithmetic manner.

Although geometric intuition is appealed to as one form of illustration, it is not the sense of the essay to depend upon it, but rather to make a purely arithmetical treatment all sufficient.

The discussion of the real nature and essence of continuity and infinitessimals is minute and painstaking but withal very clear.

The second portion of the book with like exhaustive analysis treats of the nature and meaning of numbers, and discusses the elements of different systems both finite and infinite, and also undertakes a scientific exposition of the process of addition and multiplication.

The author has elaborated much that at first sight would seem axiomatic, but a careful perusal of the work cannot fail to be a useful mental exercise and training. T. C. I.

Mathematical Essays and Recreations. By Hermann Schubert, Prof. Mathematics, Hamburg, Germany. Translated from the German by Thos. J. McCormack. Chicago: Open Court Publishing Co., 1898. 149 pages, including index. Price, 75 cents.

This volume of essays is a most pleasing presentation of fundamental mathematical truths, couched in such language and expressions as to make it particularly acceptable to those who, though greatly interested in such matters, have not devoted themselves so exclusively to them as to become finished masters.

Much relief is experienced by the average reader in the absence of intricate formulas, and the expression, "Hence it is evident," when no such evidence has become apparent.

The first chapter on Notion and definition of number is simplicity itself, and contains interesting historical data relative to different systems of enumeration.

The discussion of Monism in arithmetic follows, and it is shown how derived species of numbers, by the logical application of a single principle, flow naturally from the notion of number and of addition as before described.

The Nature of mathematical knowledge is treated in a manner to show why and to what extent the common phrase, "Mathmetically certain and unequivocal," can be used.

As "recreations" the author presents many of the innumerable forms of magic squares and polygons, the nonutility of which he excuses by saying that underlying these little riddles there is a deeper problem of great significance, namely, "the philosophical problem of the world order."

That much misunderstood idea of a fourth dimension (in space) is cleared up to the lay reader, who learns that he is not expected to conceive of more than length, breadth and thickness in objects about him. At the same time the idea of a fourth dimension, used in its strictly mathematical sense as a means of investigation, is clearly set forth.

In like manner, in treating of the squaring of the circle, it is made amusingly evident that the circle as a circle is not expected to become square.

The historical references in the last portion of the book are most interesting and instructive. T. C. I.

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NOTICE

From the dues of each member $2.00 is set aside as a subscription to the Journal.

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CXXVII.

ELECTRICAL OSCILLATIONS OF HIGH FREQUENCY.

By Arthur V. Abbott, C. E., M. W. S. E.

Presented May 8th, 1901.

The lightning's flash and succeeding peal of thunder were probably among the earliest of natural phenomena to attract the attention of primitive men, yet systematic electricity is the youngest of all the sciences. Its very name is derived from the Greek appellation for amber, as the electrical properties of this fossil gum were described by Thalos half a dozen centuries before Christ; yet it is only within the last half century that electricity can claim the slightest scientific pretentions, and prior to that very recent date there was not, apparently, the slightest probability that it would ever, in the least degree, contribute to civilization. To-day the capital invested in electrical enterprises is counted by billions; by the telegraph and telephone all nations of the world are linked together;

we have harnessed the lighting and made it draw our burdens; we have captured its flashes and it illuminates millions of lamps.

This evening I have the pleasant but difficult task of presenting to you some idea of modern belief as to the nature of electricity, but in this attempt I shall be severely handicapped, partly owing to the limited time at command, partly by the restrictions of crude and imperfect apparatus, for that which is before you is homemade, having been constructed by my friend and assistant, Mr. Edson, and myself, but chiefly by my own imperfect knowledge of the subject. Possibly, nay probably, I shall weary you by presenting experiments that may seem to all, and will certainly appear to those who are electricians, very trite and commonplace; but my defense for this course lies in the benefit I have always derived, when studying any subject, in the clearness of view that is gained by systematic reviews of that which has preceded.

In the last analysis of which the human brain is now capable, the universe is found to consist of two entities—matter and energy—and all of the phenomena which we observe, from the gyrations of the animalcule, that finds a world in the tiniest drop of water, to the rush of planetary systems through immeasurable space, may, so far as it is now possible to ascertain, be referred to the mutual actions and reactions of these two fundametal conceptions. Could we, therefore, completely cognize them, we should have traveled certainly a long way toward the ultimate boundary of useful knowledge.

We at present describe matter as *that which can move*, and energy as *that which can set matter in motion.* These definitions are disappointing, as they are so mutually correlative that we know nothing absolutely about either, but only recognize each in terms of the other, and it is in the light of these two definitions of matter and motion that I wish to speak to you about electricity this evening.

Consider the very familiar example of the pendulum. It consists of a weight suspended by a rod from a point of support. If a force be applied to the bob, such as a push from the hand, the pendulum commences to swing back and forth with ever decreasing oscillations until it finally comes to rest in its original position. To set the pendulum swinging requires the propelling hand to expend a certain amount of force, and if, after oscillation is initiated, a second hand be interposed to arrest the motion, a blow more or less violent is received. Suppose there are two pendulums, one of which has a much larger bob suspended by a longer and stiffer rod. We know, by experience, that the larger one will require a harder push to set it in motion, it will swing longer before coming to a rest and will inflict a much severer blow if violently interrupted.

The pendulum experiment draws attention to that very familiar property of matter called inertia. In daily experience we see it and

requires the application of force to set bodies in motion, and that the amount of motion produced, or momentum, is proportional to the intensity of the force, the length of time it acts, ~~and the mag~~nitude or mass ~~of the body acted upon~~. By the blow which the swinging bob delivers to the arresting hand, we are taught that the moving body has collected and stored up energy from the force that set it in motion, and that it is at any time ready to deliver up this energy when the motion is interfered with. By careful measurement it may be shown that the amount of energy thus regained is exactly proportional to that originally impressed, so that nothing is lost.

Examine now more closely the conditions of the pendulum during each oscillation. When the bob is in the centre of the arc through which it travels, it is evidently moving most swiftly and would deliver to an arresting hand the hardest blow. As it gradually rises toward the end of its path the motion becomes slower and slower, until at the end of the swing it rests for a fraction of an instant before starting on its return journey. At this point the bob could not inflict any blow, for it is motionless until it again moves downward. Thus, during each swing the energy stored in the bob changes its form; at the centre of the arc, where the motion is the swiftest, the energy is all kinetic—that is, able to act upon another body; but as the bob rises toward the end of its arc, this kinetic energy is expended in lifting the weight of the bob against the gravitation of the earth, until at the end of the swing all the kinetic energy is gone. As the energy has been expended in raising the weight of the bob, it is now said to be potential energy, for if the bob be allowed to fall, it will again reappear in a condition to do work upon another body. Thus, during each complete vibration from one side of its arc to the other and back again, the energy stored in the bob changes its form twice, from potential to kinetic and from kinetic back to potential. In Longfellow's "Old Clock Upon the Stairs" you will remember—

> "Somewhat back from the village street,
> Stands the old fashioned country seat;
> Across its antique portico,
> Tall poplar trees their shadows throw,
> And from its station in the hall
> An ancient time-piece says to all,—
> Forever—Never—Never—Forever."

But scientifically the old clock should have ticked "Potential—Kinetic—Kinetic—Potential."

If it be true that careful measurement shows that all the energy delivered to the pendulum to set it in motion is recoverable, then why does it not continue to swing forever? Why does it finally come to rest? We believe that energy is as indestructible as matter. What, therefore, finally becomes of the force that was originally impressed upon the bob? As the weight with its suspending rod moves to and fro, it must push aside the air particles to make room for itself, so at every swing a portion of the original energy is dissipated to overcome air resistance. It is also impossible to devise any form of support that shall be absolutely frictionless, and another part of the energy is thus consumed in this manner. In order to reduce such losses to the minimum, it is now customary to suspend the pendulum by means of a thin, flexible strip of metal or a spring. In this case there is no friction, in the ordinary sense of the word, but a certain amount of the impressed energy is used in bending the particles of the spring; but, like the change from kinetic energy to potential energy, this portion is stored and restored during each oscillation. Therefore, in the case of the pendulum we must consider four quantities. First, a certain amount of force at command to set the pendulum swinging. Second, the weight or inertia of the bob. Third, the elasticity of the suspending spring. Fourth, the resistance of the air through which the mechanism moves. So, if a given definite amount of force is expended in starting a pendulum, it will be found at any instant of time afterwards that the energy dissipated in friction, plus that stored in the pendulum, is exactly equal to the original quantity, and that at any point during each swing the stored energy may be divided into three parts:

First, the kinetic energy, due to the speed and the mass of the swinging weight.

Second, the potential energy, due to the mass and position of the bob above its lowest point.

Third, the energy used in bending the supporting spring, which is proportional to its coefficient of elasticity.

When the bob is at the center and the speed at maximum, the spring is straight, hence all the energy is kinetic. When the bob is at its highest point, all of the energy is potential and divided between that used to raise the weight of the pendulum against gravity and that expended in bending the supporting spring. Finally, when the pendulum has come to rest, all of the impressed energy has been dissipated in overcoming the resistance of the air.

I have developed the theory of the pendulum at length because, in dealing with electricity, we find conditions that seem to be exactly similar, and a vivid, mental picture of a mechanical analogy will enable one to realize with greater clearness the more obscure electrical phenomenon.

In every electrical circuit four quantities claim attention:

First, there is a certain amount of force in the form of electricity.

Second, in transporting this electricity from place to place, resistance is encountered, which, like the opposition of the air to the swinging bob, dissipates a certain amount of the original force.

Third, when electricity is moved from point to point, a definite, although very short, time is needed to accomplish the transfer. We know it takes time to start the pendulum, and term this delay inertia. So in an electrical circuit the time required to produce an electrical effect makes us think of inertia so strongly that this property has been called *electrical inertia*, although now it is usually termed inductance. Indeed, so strong is the resemblance that many scientists have maintained that, for this reason, electricity must be a substance, or some form of matter.

Fourth, every electrical circuit behaves as if it could hold a definite quantity of electricity, and, moreover, the greater the electrical pressure the more electricity can be squeezed in, or the circuit behaves as if it were electrically elastic. This property is called *capacity*.

Now at every moment after a definite amount of electrical force has been impressed upon a circuit, it is found that the quantity of energy dissipated as heat, plus that stored in the magnetic field around the circuit, plus that stored by the capacity of the circuit, is exactly equal to the original quantity, and that if the electrical pressure be removed, the magnetic field and the capacity give up and restore the energy they have absorbed. Thus an electrical circuit is analogous in all points to the mechanical illustration of the pendulum.

I will now try to illustrate these facts by some experiments.

Here is a piece of fine iron wire about a yard long, supported upon two stands so as to hang freely in the air. At one end there is a coil of heavy copper wire having about 200 turns. By means of a switch Mr. Edson can connect the wire with the Edison mains. As he does so the wire glows red hot. To the passage of the electricity the wire has offered so great a resistance that the electrical energy is changed into heat and causes the wire to become incandescent. This is precisely similar to the action of the pendulum, for with delicate instruments it could be shown that the resistance offered by the air has resulted in a slight heating, both of the surrounding atmosphere and of the matter forming the mechanism of the pendulum.

Now for the steady electrical pressure of the Edison mains I will substitute an alternating current, or one which fluctuates rapidly from a positive to a negative value. Notice that, although in both cases the electrical pressure is the same, the wire no longer glows but remains black. I will now place a piece of wire across the ends of the copper coil; immediately the wire glows red hot. Why is this? It will immediately occur to you that by means of the piece of wire I have short-circuited the copper coil and removed its influence from the circuit. True. And now I will repeat the experiment of short-circuiting the coil with the Edison current. You see that no perceptible effect is produced. Evidently it is not merely the presence of the coil that has prevented the wire from becoming incandescent. You will remember that I stated that electricity behaved as if it had inertia, requiring a certain time to assert its presence in a circuit. If, therefore, the electrical impulses recur with great rapidity, the inertia of the circuit may be so great as to prevent electricity from manifesting itself.

Suppose we had a pendulum with a large and heavy weight. A succession of light alternating blows might be unable to set it swinging, while a steady push, no greater than the sum of the taps, could accomplish the desired result.

Again, suppose we take off the large weight and substitute a small one, then a slight tap may set it in motion. This is exactly the case with the coil of wire. The Edison current gives a steady push, while the alternating one is a succession of taps repeated at the rate of 133 per second. With the coil attached to the wire, the steady push of the Edison current can manifest itself by causing the wire to glow, while the alternating current is not able to produce this effect. If I cut out the coil, which corresponds to changing the heavy bob for a light one, or to decreasing the inertia, then the rapid alternating impulses can produce the same effect as the steady application of the Edison current. Electricians term this property *impedance* from the very self-evident property of the coil to impede or restrain the passage of electricity.

We must ascertain, if possible, the cause of this impedance. We are all familiar with the peculiar state that iron sometimes assumes, by which it is enabled to attract other pieces of iron, and which we term magetism. Here is an iron bar that is a magnet, and a good one, as it will easily lift a score of pounds. Probably you will notice a coil of wire on the magnetized bar. I will remove the coil, and now the bar is no longer a magnet and refuses to lift even a tack. Replacing the coil the bar becomes a powerful magnet. I will disconnect the coil from the Edison mains and again the magnetism vanishes. If the bar be removed from the coil and the current switched on, the coil, although of copper, is made quite a powerful magnet and will pick up a pile of nails or a heavy bolt. Evidently the magnetism was not in the bar, nor in the wire coil, nor the combination of the two, but was due to the presence of *electricity* in the coil. This magnetic influence extends through considerable space around the wire, for the coil can draw to itself a nail from a distance of a foot or more. By placing an iron rod loosely inside of the coil, and opening and closing the circuit switch, the bar hops up and down and we have a veritable electric motor. By means of magnetism the electricity is doing mechanical work, for it is lifting the iron against gravitation, and when the bar drops the energy thus expended is given out; so around every wire that conveys electricity this mysterious magnetic field exists, in which energy is stored up in a manner analogous to that which takes place when the pendulum bob is pushed. Time is required to create a magnetic field, and during this interval energy is being absorbed by the space surrounding the wire, and therefore during this period the electricity cannot produce other effects.

Now if the electrical impulses vary more rapidly than magnetization can be accomplished, all the energy will be expended in producing the magnetic field and none left for other purposes. This is exactly what occurs in the case of the coil and alternating current. The electrical energy is expended in the space around the coil, and by the time the magnetic field is fully created the current is dying away and the process must be repeated; but cutting out the coil is equivalent to removing the impedance or electrical inertia, thus permitting the alternating current to heat the iron wire in a manner similar to that produced by the Edison mains.

If electricity, by storing energy in the magnetic field, can initiate magnetic phenomena, then the converse proposition should be true, and given a magnetic field, it should be possible to derive electricity therefrom.

Taking the same iron bar and magnetizing coil previously used, I place on the end of the rod a second but entirely separate coil of wire, to the ends of which a small incandescent lamp is attached. When the switch is closed and the bar magnetized by the Edison current, the lamp emits a flash, and again when the switch is opened a second flash shines out. By working the switch with considerable rapidity the lamp may be kept almost continually alight; so it is shown that electricity and magnetism are mutually interconvertible, either being capable of producing the other. It is noteworthy that the lamp flashes only at the opening and closing of the switch; that is to say, when the magnetic field is made and unmade. This indicates that when electrification takes place, the Edison current is employed in storing energy in the magnetic field; and again, that when the current is broken and the coil de-electrified, the energy previously stored in the magnetic field is restored and given back to the circuit from whence it had its origin.

If the switch could be opened and closed with sufficient rapidity, the lamp would evidently remain constantly lighted, but obviously the same result can be much more conveniently secured by using an alternating current, thus avoiding the mechanism of the switch.

I will now change the connections from the Edison current to the alternating one, and you see that the lamp remains continuously lighted. Someone will immediately reason that if the alternating current passing through a wire coil and an iron bar can set up a changing magnetic field that can excite electricity in the second coil, the turns of wire in the first coil must naturally react among themselves and set up counter currents that oppose each other. This is precisely what occurs. When the electrical state of a coil is changing, each coil of wire reacts upon all the others, setting up counter electrical actions that tend, when the original current is increasing, to oppose its rise, and when it is decreasing, to oppose its fall. Such action produces the effect called impedance.

To illustrate this principle still further. Here is a large lamp, to the base of which a wire coil is attached and the whole contrivance placed in a jar of water, so that it floats. Setting the jar on the top of the alternating magnet the lamp is at once illuminated, and, moreover, as it slightly rises in the water a certain repulsive action must take place between the coil and the magnet. Raising the jar, I place a copper plate between it and the magnet. The lamp is at once extinguished, for the energy of the magnetic field is now expended in producing electric currents in the copper plate, and the lamp coil is therefore screened and no electricity developed to illuminate the lamp, but the copper plate becomes quite hot, as you can readily feel. Cutting off the alternating current, I place another copper plate upon the alternating magnet. To an ordinary magnet a copper plate is, as you know, quite indifferent. On closing the circuit the copper plate is violently repelled and thrown some distance into the air, thus forcibly illustrating the repulsion previously shown by the floating lamp.

I pass a knitting needle through a hole in the center of the plate to prevent it from flying away, and the plate floats in the air some six inches above the magnet. Now it commences to rotate, and soon is spinning several hundred times a minute, making a very practical electric motor. Removing the lamp from the jar of water I substitute a hollow floating copper ball; on setting the jar over the magnet the ball commences to spin, and it soon rotates with such violence as to leap from the jar.

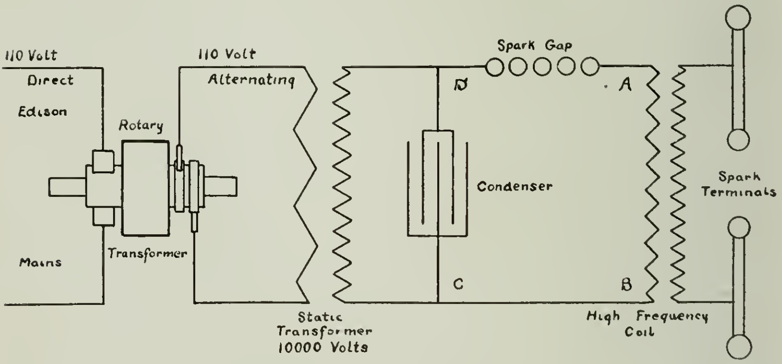
All these experiments are simply illustrations of the fact that by means of electricity, energy may be stored in the magnetic field surrounding a conductor, and that with the proper apparatus this energy when released may be utilized. So far we have dealt with but two of the fundamental properties—resistance and inductance. We must now consider capacity.

All electrical conductors appear to be able to hold or retain a certain quantity of electricity. The experiment of a bottle or jar coated inside and out with tin foil, from which a spark may be obtained, is so familiar that I forbear to repeat it. In modern language a Leyden jar is called a condenser, probably from its seeming ability to condense or confine electricity within itself. To obtain capacity of any magnitude by means of the old-fashioned Leyden jars required the employment of a large number of glass bottles. Now condensers are made of alternate layers of tin foil and sheets of mica. Here is one in a wooden box, only about eight inches on each side, that has as great a capacity as could be obtained by several hundred jars. I connect the terminals of the condenser to the Edison mains; then removing the wires I touch the terminals with a metal rod, when a bright flash and sharp crack show that considerable electricity has been stored in the condenser. There s another binding post in the center of the box to which only half as many plates are attached. Repeating the experiment with this post a similar but smaller spark and snap show that, as one would expect, the storing power of the condenser is proportional to the size. Let me now repeat the experiment, using an electrical pressure which is twice as great and then half as large as in the first instance. With the higher pressure of 220 volts the spark is a detonation, while with 50 volts it is hardly perceptible. Hence the capacity of a condenser varies with the electrical pressure, so that condensers appear to be elastic.

Let us take an analogy. Here is a jar of water having a tube connected to the bottom leading to a rubber bag. If I raise the jar slightly, the increased head or water pressure causes the water to flow into the bag and distends it against its own elasticity. If the jar be lowered, the bag contracts and forces the water back again. Hence the capacity of the rubber bag may be measured in terms of the water pressure, for the greater the pressure the more the bag can hold. A condenser acts in precisely a similar manner.

Such is, very briefly and imperfectly, an outline of the behavior of the three fundamental attributes of every electrical circuit—resistance, inductance and capacity. Resistance acts to dissipate the electrical energy, while inductance and capacity operate to store up and retain the energy in such a manner as to permit it to be subsequently recovered. Curiously also, inductance acts in a manner opposed to capacity. When a circuit is electrified, inductance tends to set up a counter electro-motive force that opposes the transfer of electrical energy, while on the other hand capacity acts as an elastic electrical tank that courts an inrush of current. Evidently it is possible to so adjust the mutual relations of inductance and capacity in any circuit so that they should exactly balance each other and leave the circuit as if it were devoid of both. Under such circumstunces a circuit is said to be in resonance. Very peculiar results may follow in such cases.

Here is a bank of eight lamps in parallel; connected in series with them is a condenser and a large coil of wire. I connect the terminals of this circuit to the alternator and at once the lamps burn brightly. Here are two more lamps connected in series by a heavy wire that I will use as a rough detector. All the lamps are regular 110-volt lamps, and the brightly burning bank shows that the alternator has developed 110 volts. If I place the detector lamps across the terminals of the alternator, the bank of eight lamps is unaffected, while the detector lamps glow very dimly, as would be expected, for 110 volts cannot illuminate two 110-volt lamps in series. I will now place the detector lamps across the terminals, first of the condenser and then of the wire coil or inductance. In both cases the detector lamps light up to full brilliancy, while the bank of lamps grows dim. Two things are proved: First, that notwithstanding the alternator gives but 110 volts, there are 220 volts around the terminals both of the condenser and of the inductance. Second, shunting out either the condenser or the inductance in an alternating circuit paradoxically increases and not decreases its apparent resistance. Thus by a judicious manipulation of inductance and capacity in the circuit before you, I have doubled the electrical pressure of the generator. Such a result opens before the imagination wide possibilities, and the apparatus which I shall now show you owes much of its somewhat surprising results to the utilization of this principle.



By means of a rough diagram I will describe the chief features of a high frequency coil such as is on the table. First, there are the Edison mains which furnish a supply of straight current at 110 volts. To them is attached a small rotary transformer, the function of which is to convert the straight current into an alternating current at 110 volts with a frequency of 133 periods per second. Now comes a static transformer, which raises the potential from 110 to 10,000 volts. Across the leads from the 10,000 volt transformer a condenser is placed, made of sheets of tin foil immersed in oil, each being separated by an excellent insulating paper made by the Central Electric Company. From the condenser one side of the circuit passes directly to one terminal of the primary of the high frequency coil that consists of nine turns of copper ribbon, ¾ inch wide and .035 in. thick, wound around a kind of squirrel cage made of strips of wood. The other side of the circuit passes from the condenser to a spark gap made of five aluminum balls, two of which are adjustable with reference to the other three, giving a graduated quadruple spark gap, and thence to the other terminal of the primary of the high frequency coil. The secondary of this coil consists of 280 turns of cotton covered No. 24 wire, wound an a paper cylinder and placed inside the primary, the whole affair being immersed in a papier-mache jar filled with oil. The operation of the coil is as follows:

Twice during each period the static transformer charges the condenser; when the potential rises sufficiently to overcome the resistance of the air gas, the condenser discharges. As the inductance of the secondary of the static transformer is very high, essentially all this discharge passes through the primary of the high frequency coil. Lord Kelvin has shown that for every electrical circuit containing resistance, inductance and capacity, the discharge from the condenser will be oscillatory, when the resistance is less than the square root of the product of the inductance and capacity. If R represents the resistance, C the capacity and L the inductance, this relation is explained by the formula, $R < \sqrt{L\,C}$. In the circuit under construction, if the resistance of the spark gap connecting wires and primary is less than the square root of the product of the inductance and capacity, the electrical charge of the condenser will be a series of recurrent impulses that rush to and fro around the circuit, *A B C D*. In one of the previous experiments it was shown that the presence of an alternating current in one coil of wire was sufficient to excite electricity in an adjacent one. It is also easy to show that the results obtained in the secondary coil are proportional to the amount of electricity passing in the primary, and to the rapidity with which it oscillates. If the resistance of the circuit is very small, which is the case in the apparatus before you, the rapidity of the alternations or frequency is given by the expression $n = \frac{5,000,000}{L\,C}$, in which n is the number of oscillations per second, L the inductance of the circuit and C the capacity. In this apparatus the condenser can be varied from .005 to .058 microfarads. Including the inductance of the leads, L has a value of .013 "henrys," and hence

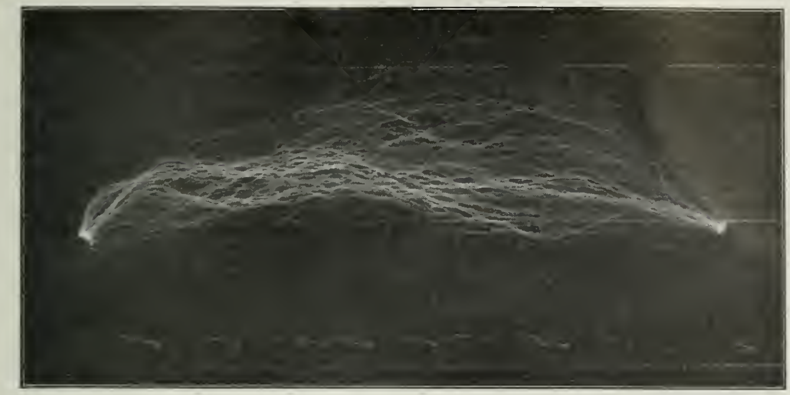
$$n = \frac{5,000,000}{\sqrt{(.013x.005)}} = 616,000 \text{ per second.}$$

$$\text{and } n = \frac{5,000,000}{\sqrt{(.013x.058)}} = 178,000 \text{ per second.}$$

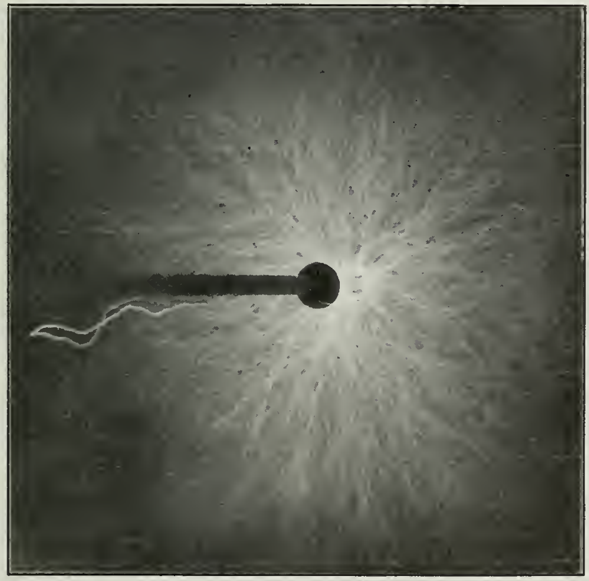
Potential measurements show that about 200,000 volts are developed, so that the coil is capable of giving upwards of 20-inch spark. With such electrical pressures and frequencies many curious and somewhat paradoxical phenomena appear.

Here is a piece of No. 00 copper wire bent in the shape of a U with legs about three feet long, so that the total length of the wire is about six feet. At various points along the U little copper hooks are placed, on which I hang incandescent lamps in such a manner as to bridge from one side of the U to the other. The resistance of the U is about .0004 ohms and that of the lamp about 200 ohms, so that the lamp presents 50,000 times as much resistance as the copper U. I attach one end of the U to the condenser and the other to the spark gap, adjusting the condenser to give about 600,000 alternations per second. On closing the switch some of the lamps immediately glow, notwithstanding they are shunted by an almost infinitely low resistance. In an earlier experiment the impedance of a coil of copper prevented the iron wire from glowing. Here the impedance on a short rod is sufficient to force electricity through an alternative path against a resistance 50,000 times as great. But why do some of the lamps burn brightly, others dimly, while others are black, even although shunted by a longer bar? Here is a cotton cord; by a twist of the hand I can set it swinging in exactly the same manner as a sounding piano string vibrates. Certain portions of the cord swing through large arcs while others are nearly still, and the quiescent points subdivide the cord into definite equal parts. Such points of rest are called nodes in music, and the experiment with the copper U proves the existence of electrical nodes. The discharge from the condenser is a wave that travels along the rod; at points where the crest of the wave appears the lamps glow brightly, but at the hollows they are black and at intermediate points correspondingly dim.

The relative inductance, capacity and resistance affect curiously the character of the discharge from the coil. Inserting all of the condenser, a white, flaming arc as thick as a lead pencil is produced, that jumps some fifteen inches between the terminals with a continuous hissing roar. By equipping the terminals with a pair of large sewing needles and shortening the arc, the needles may be volatilized with the customary scintillation of burning steel. By inserting inductance in the circuit the character of the discharge is entirely altered. It loses the arc-light character, becoming thin and thread-like. The discharges take place at longer intervals, emitting a pale, violet gleam, and in fact with sufficient inductance all of the phenomena of the largest Holtz machine may be repeated. Extinguishing the lights and setting the coil at work, all parts of the apparatus are covered with a phosphorescent glow. By reduc-

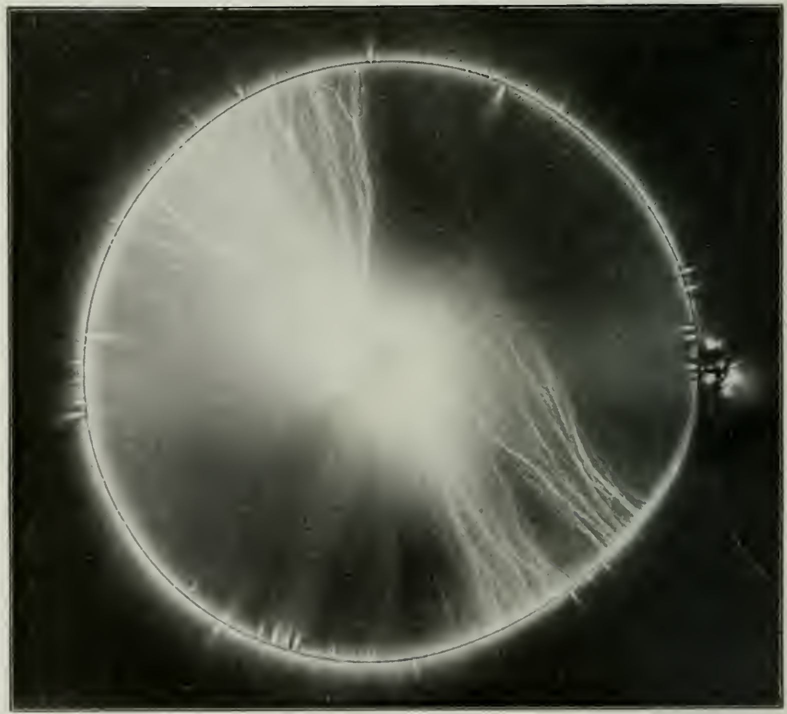


Photographic reproduction of 15-inch Spark with inductance introduced into the circuit.



Photographic reproduction of violet brush at pole terminal, with a frequency of oscillations of 600,000 per second.

ing the condenser to its smallest limit the frequency is raised to 600,000 per second, and then sparks no longer pass between the terminals, but instead each pole emits a violet brush that envelops it in a pale flame shooting a foot or more into the air. Placing a large brass ball on one of the terminals and approaching the hand toward the other one, sparks dart from the fingers to the sphere, but owing to the high frequency there is absolutely no sensation. The impedance of my body is so great that, while there is abundant energy to kill, the alterations are so rapid that there is no time to affect the vital organs. Indeed I may approach my hand so closely to the coil that a shower of sparks passes. There is a slight burning sensation at the tips of the fingers, and tomorrow a few blisters will appear, as the spark is intensely hot, but no other sensation is experienced. Equipping my hand with a metal rod, sparks may be taken with impunity. Stepping upon a glass plate supported by four tumblers, so as to insulate myself as perfectly as possible, and offering the metal rod to one terminal of the coil, a rush of sparks passes to my hand, notwithstanding the fact that I am completely insulated, for with such high frequencies most bodies possess so great a capacity that electrical action may be carried on with one wire instead of two. To place a plate of glass between the terminals on an ordinary induction coil simply stops the dis-



Photographic reproduction of effect of a violet wheel with the high frequency discharge from the terminal at the center to a wire ring two feet in diameter.

charge. Setting the poles of the high frequency coil so that no discharge takes place, and inserting a glass plate, causes a rush of sparks to the plate that spread into a network a foot in diameter, and in a minute or so the glass is pierced. You can also see by touching it that it is intensely hot.

Here are two wires supported on wooden stands extended down the room. Attaching them to the poles of the coil, each one glows its entire length with a cylinder of violet light, while between the wires there is a continuous phosphorescent discharge. Equipping one pole with a metal rod and the other with a wire ring some two feet in diameter, of which the knob forms the center, a violet wheel of flame is produced. Here is a little aluminum vane that I will place on a needle point set upon one of the terminals. Holding a metal screen connected to the other pole a foot or more above the vane it commences to rotate, and is now revolving in a cylinder of light, thus giving a motor with but a single wire. Taking a piece of wood a couple of feet long and two inches in thickness I place it across the coil poles. The first spark rends the wood as a lightning flash does a tree, and now the whole stick is in flames.

Here, to use an electrical term, is a high frequency transformer, consisting of a glass jar, on the inside of which there are some 300 turns of fine wire on a paper cylinder, while on the outside are five or six turns of copper strip. I place the jar on the glass plate resting on the tumblers, so that it is completely insulated. I also connect an ordinary 110-volt electric lamp across the terminals of the copper strip and attach *one end only* of the inside wire to the high frequency coil. Immediately the lamp lights to full brilliancy. Standing on another glass plate, and touching one pole of the coil with the hand, I light up the lamp by presenting my other hand to the transformer.

On these two wooden stands are a couple of zinc plates about four feet square. I set one at each side of the room, so that the distance between them may be as great as possible. I have a number of glass tubes varying from two to eight feet in length and about two inches in diameter. From all of them the air has been exhausted as completely as possible. There are no leading-in wires, no carbon filaments or other devices—nothing, in fact, but the infinitely tenuous residual atmosphere that the best mercury pump cannot remove, yet the high frequency coil will fill the room with electrical waves radiating from the zinc plates, and the residual gaseous atoms in the glass tubes can in some mysterious manner pick up the radiated energy and translate it into light. Lowering the lights I take a tube in each hand, while my assistant does the same, and you will see that, no matter where the tubes may be waved about, all are brilliantly illuminated. I will now take the

8-foot tube and hold it so that its center falls upon the intersection of two lines, one drawn through the axis of the coil and the other through the zinc plates, when under these circumstances the tube is vertical it remains dark, so that there is a neutral plane that passes through a vertical, drawn through the coil center, but if I swing the tube a few degrees on either side it at once becomes illuminated.

In the light of the crude illustrations I have been able to place before you this evening, it is evident that the recent electrical progress has endowed us with a further and deeper insight into the fundamental constitution of the universe than was previously possessed. During the early part of the century just completed, the atomic theory of Dalton engaged the attention of the scientific world. This hypothesis assumed that all matter was resolvable into a comparatively small number of different elements incapable of further analysis by any process. Physically each element could be reduced to particles of very minute yet perfectly appreciable dimensions called atoms, while an attempt to subdivide the atom would, if it could be conceived of, as successfully result in its destruction—at least in the material sense. The atoms of the elements possessed the power of entering into combination with each other in varying proportions, forming molecules that exhibit properties completely different from those of their constituents, while molecular aggregates form the universe as we know it. Some idea of molecular dimensions may be gained from Lord Kelvin's illustration that if a drop of water should be magnified to the size of the earth's orbit, or 180,000,000 miles in diameter, the molecules would appear larger than marbles and smaller than base balls.

Recently it has been shown by experiments too delicate to present to a large audience, that by electrically acting upon many of the elements in the gaseous state, it is possible to split up the so-called atoms into portions that are from 1,000 to 2,000 times smaller than all preconceived ideas indicated possible. Such bodies have now received the name of corpuscles, and we are further confronted with good evidence that the corpuscles obtained by electrical analysis from different elements exhibit the same physical properties, or, in other words, that corpuscles obtained from hydrogen are the same in all respects as those obtained from oxygen. This leads to the very startling proposition that in an ultimate analysis there is only one kind of matter, and that the whole physical universe is but a vast phantasmagoria of Protean changes wrought by one fundamental form of force acting on a basic form of matter.

Did you ever watch a skillful smoker puffing smoke rings from his lighted cigar? They possess most remarkable properties. They twist and turn, elongate, contract, turn inside out, pass through and around each other, and yet each persistently retains its own individuality absolutely unchanged. Conceive the luminiferous ether—that wonderful fluid of the existence of which there is all but the most absolute proof—as a vast stagnant ocean repleting all space. Imagine, further, that here and there, in some at present incomprehensible manner, a force to act upon the ether, producing centers of strain. At such points the ether would be disturbed and set into countless whirling eddies or vortices, in all respects analogous to the smoke rings.

Lord Kelvin has shown mathematically that such a condition of affairs is sufficient to explain all of the physical conditions of matter as we know it. Recent electrical progress supports this assumption, and, further, points to the hypothesis that electricity is tangible evidence of the vortex ring. Scientists are now talking of the atom of electricity termed an electron, meaning thereby an elementary ether whirl. If all the existing kinds of matter can be *analyzed* into one basic form, it is certainly conceivable that this elementary substance could be synthesized into an entirely different kind of matter than that from which it was first derived. Such an achievement would realize all of the dreams of the alchemists and substantiate the theories of the Rosecrucians. The immensity of this conception and its possible effect upon human affairs paralyzes even the most daring imagination, so that only the future can deal with possibilities so tremendous.

CXXVIII

THE FORESTER, AN ENGINEER.

By B. E. Fernow,

Director of the New York State College of Forestry, Cornell University,
Ithaca, N. Y.

Presented June 26, 1901.

There is hardly any business concerned in the manufacture or production of materials which does not require some knowledge on the part of the producer as to how to adopt means to ends, how to use mechanical and physical properties of matter in construction and locomotion, and in applying this he fulfills the definition of an engineer. The forester's business is one in which the need of engineering gumption and knowledge appears in various directions so prominently that he can without impropriety be called a specialized engineer, and in fact the title of "Forest Engineer" is given to the graduates of forestry schools in several countries.

Forestry, in plainest terms, is the business of wood production, including the harvest of the produced material. The difference between the logger and the forester is that the former is a harvester of nature's crop, a mere converter into useful shape of a crop to the production of which he has contributed nothing, and to the reproduction of which he does not pay any attention, while the forester, who harvesting the naturally grown wood crop, does so with a view to its reproduction.

Nature produces weeds—tree weeds—and useful species side by side. She does not care for the composition of the crop; she has no concern with the form of the component trees they may be branched and crooked, short and tapering, too slowly or too rapidly grown for satisfactory quality. In time, in a long time, she too may produce long, clear shafts, but by her methods such results will only be accomplished in centuries. The area of virgin forest which we harvest to-day has produced a tithe of the useful material which it is capable of producing, and has taken two to threefold the time which it would take under skillful direction to secure better results, quantitatively and qualitatively. The trees which we in the United States are now converting into lumber are mostly from 200 to 300 years old; and while here and there an acre has produced to its full capacity, say 100 cubic feet of useful wood per acre per annum, the average has probably not attained one-tenth of this production. The time element is left out in nature's calculations; whether it grew the 10,000 feet, B. M., which we find on an acre in 50 or in 100 or 1,000 years is no concern to her.

The forest of the forester, then, will differ considerably from the forest which nature produces. The forester introduces the economic point of view, preparing to secure the largest amount of the most useful material in the shortest time. Finally, he is in this business, like other business men, for the purpose of making money out of his crop, and therefore we should add that he is trying to secure this result with the least possible, yet adequate expenditure.

A Spruce Forest in Germany.

The one thing in which the forestry business differs from all other business is the long-time element, for it takes a hundred years and more to grow trees fit for the use of the engineer, the builder and the architect, hence the dollar spent now in its first start must come back *with compound interest* a hundred years hence. This long-time element entails careful planning, entails economy and prevision. Hence, all the forester does must be done with permanency in view. And here again the lumberman and forester differ in objects, and therefore in methods; the one treats his property as a speculation, a temporary occupancy; the other treats it as an investment; permanent management, continuity of occupancy, is the basis of his actions.

The first step in taking hold of a forest property is, therefore, a survey of the same, not only of its boundaries, but of its tópography and character, as well as of its contents. Surveying, both line and topographical surveying, are requisites of the competent forester. While such a first survey might be made by regular surveyors as the work of the forest manager progresses and needs recording on the maps, it will be found useful if he can do his own surveying, and thereby become competent also to interpret readily topographic maps. Such surveys, being not for general map purposes, but with engineering work in view, must be made with more care and on a larger scale than is usual with such field maps as, for instance, those of the Geological Survey.

The next direction in which engineering knowledge is required is in the locating and laying out and constructing of roads and other means of transportation, for the property to be accessible in all its parts is finally of greatest importance in managing a property for permanency. In our undeveloped conditions, especially in the absence of local markets, we may still be satisfied with a minimum of permanent road system, substituting temporary roads and means of transportation, and leaving to future generations their further development; but the plans should be made for permanency from the start, even if their execution is delayed. Cheap but efficient road building and railroad building, I am afraid, is a matter with which even few engineers are well acquainted; it is a subject in which the forester is intensely interested. These means of transportation are, of course, needed to remove the harvest, and to handle this bulky material cheaply requires no mean engineering gumption.

The Forest Harvest to be Moved, College Forest, N. Y.

What an important item this moving of the wood crop is may be realized when we consider that the annual wood harvest of the United States represents not less than 500,000,000 tons of material to be moved shorter or longer distances, and if we consider only the sawed material, at least 150,000,000 tons must be handled in various ways, from stump to rail and market, at least four to five times. This is, indeed, engineering work of no mean importance.

In reproducing his crops the forester has various methods of procedure. The simplest one that suggests itself is the one the farmer follows, namely, to harvest the crop and replant it—artificial reproduction. The forester has learned that this is not necessary, that he can from the seed of the trees which he finds on the ground secure an aftergrowth—natural regeneration. Having studied the life habits of the different species with which he has to deal and their requirements, especially as to light, he can, by gradual removal of the mother trees by skillful use of the ax, establish his new crop. But, to be sure, in order to secure the reproduction of only the useful kinds, he must first go through the weeding process, and with the mismanaged natural woods from which the lumberman has culled the desirable kinds and left all that was undesirable, a great deal of weeding and often artificial replanting of desirable kinds will be necessary.

Both proper economy and the satisfactory development of the young crop requires not only the removal of the valuable part, but of the less valuable, the cordwood, and if possible the brush, which is a hindrance to the young crop and increases the danger of fire. In such hardwood forests as we have to deal with in the Adirondacks almost every tree is damaged, has rotten parts, and altogether the cordwood represents about three times the amount of material which is found in logs; to market the cordwood, is therefore, the greater problem.

The first task of the forester, then, in beginning the management of a forest property is to provide cheap and efficient means of transportation for the removal of a bulky crop, of which much is inferior, and if possible to so arrange this harvest that it may be made gradually, logging over the same area for a number of years.

Here, in the harvest, logger and forester have similar, yet not identical interests, for the logger lacks the requirement of logging over the same area gradually, of having to remove cordwood, weeds and debris, of caring for the young aftergrowth. Nevertheless, the forester must naturally do much the same as the lumberman, and utilize the engineering skill which has been developed in the logging business.

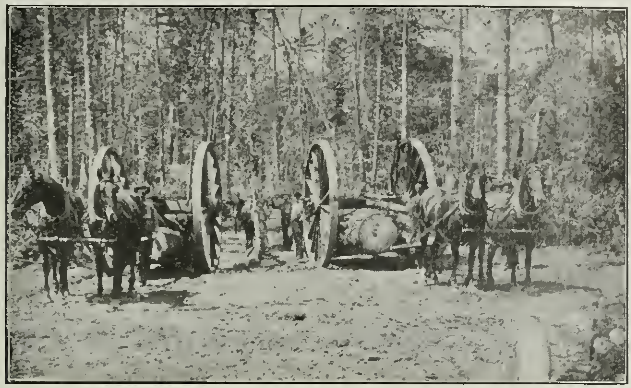
According to the size and location of his property and the working capital at his disposal, he will resort to old-fashioned methods of logging—skidding the logs by horses or mules to skidways, and hauling them on wagons or with sleds on ice roads to the landings; or using lumber slides and water flumes to bring the material either to rivers, which he may have to dam and regulate in their course in order to float and drive or raft softwoods, or to rail if hardwoods; or else he may benefit from the development of steam logging devices in connection with steam railroads.

Whether the transportation is by rail or water, or by sled or wagon, the locating of the roads is one of the most important functions of the logger. Be it that temporary winter roads or permanent summer roads are to be used, a well planned system of main roads and branches must be located. So important, for financial

Skidding Logs by Horse Teams.

Winter Hauling on Snow.

reasons, is this question of road location considered in the German forests, where continuous use of the roads is contemplated, that a permanent road system is the most important initial investment, and careful surveys and plans are made before any road is built. With us, still working on extensive and undeveloped properties, impermanent ways will still for some time be sufficient, and logging by steam on temporary roads has been, and is still to be, more fully developed.



Summer Hauling on Wheels.

While in the South tramways, or logging railroads, on which cars were hauled by animal power were first employed, the first steam logging railroad was built in 1876 at Farwell, Michigan, by W. S. Gerrish, who was denounced as a hare-brained enthusiast for his innovation, which, however, proved successful. Ten years later many such logging roads of 25 and even 45 miles in length; and altogether over 3,000 miles were in existence. In Michigan alone were over 720 miles. Now the logging railroad has become so general that the mileage may be estimated to exceed 25,000 miles.

There are still three different kinds of logging railroads in use: The pole road, the tramway with sawed wood rails with or without strap iron capping or flat bar iron rail, and the iron or steel T railroad. Each road has its merits and advantages of its own in given situations, although the regular steel T railroad, all things considered, seems to have found most favor.

Pole roads, constructed of straight round poles from 6 to 8 or 12 inches in diameter, laid with or without ties and pinned together, the gauge being 60 inches, are used mostly in the South, either with animal power or light locomotives. They recommend themselves for their cheapness in first construction, the cost amounting to $100 to $200 per mile; but they can haul only light loads, since the equipment must be light, and the cost of repairs is relatively considerable. Hence their application is confined to the exploitation of small tracts on reasonably level ground, or for short distances as feeders to a river or main road.

The use of the wood rail also recommends itself only by the saving in first cost, which may be kept at from $300 to $800 per mile; but this saving is soon obliterated by repairs and inefficiency, so that their use is generally abandoned and gives way to the steel T rail.

Both narrow gauge and standard gauge are being used, the latter where direct connection with regular standard gauge railroads is to be made, in order to avoid reloading, or where the expectation is that the logging road will become a road for varied traffic. These considerations also determine in part the weight of the rail. From 20 to 30 pounds per yard fill the requirements of a good narrow gauge, and 30 to 40 for a good standard gauge, although 45 to 70 pounds have been used; a rail somewhat heavier than the actual necessities saves in roadbed construction. In the Cornell College forest a standard gauge with a 40-pound steel rail has been used on spurs, and a 46 pound rail on the main road, with a 27-ton engine.

Skidding Logs by Oxen and by Steam to Loading Yard.

The economical construction of logging roads which are designed to serve only a temporary requirement is one of the engineering problems which more and more interests lumbermen, and even to a greater extent foresters, who are forced to secure even greater economy, since the margins from their business are for a time at least necessarily smaller. In such roads cuts and fills must be avoided as much as possible, while heavy grades, numerous and sharp curves are necessarily to be extensively used, and it takes a careful weighing of saving in cost of first construction against losses in maintenance and efficiency, such as no engineer is called upon to make in constructing standard roads. It stands to reason that to secure the least expensive logging roads, the main effort must be made in the location of the road, for this influences not only the cost of constructing, but of operating it. No rules but engineering gumption must determine. Where wood is cheap and right at hand, it is often indicated to use imperfect and unmarketable logs instead of earthwork or matting of brushwood and cribbing for crossing swamps, and similar devices which do not commend themselves for main lines. Again, landing places and terminals must be located with circumspection, to take care of the bulky material and secure the cheapest handling of it, which, with cordwood even more than with logs, depends upon the character of the landings.

In loading logs there are now very generally employed steam loaders, of which several patterns are on the market; hoisting engines with outhaul ropes running over drums, which pick up the logs alongside the track. Various devices are resorted to to facilitate the passing of cars and to locate the loader with reference to cars and landing places.

In the "Barnhart" and in the "American" Loader this is accomplished by having rails laid on the cars on which the loader travels, pulling itself along as needed, the latter on two short portable sections of track, the former on permanent track. Such a loader of the Barnhart type as used in the College forest will pick up and load from 600 to 800 logs per day, the logs being banked to within 100 feet or so from the track. It is able to move on a pivot in all directions, and the character of the landing place is of little importance.

In the "Decker" log loader the clearing of the track for bringing empties to the loader is accomplished by allowing them to pass underneath the loader over a three-rail section of track, which rises from the main track and is carried by the loader on its lower story. This machine is self-propelling, but, remaining stationary, seems to have less reaching power than the pivotal ones before mentioned.

The Lidgerwood Company, of New York, also makes a log loader in connection with their skidding device, to be described later.

In European forest work wire tramways and portable railroads are used to a considerable extent for transportation out of the woods, but these seem so far not to have found favor with us. The wire tramways, with either single or double ropes, are mainly employed in transporting logs from steep mountain sides. The wire tramway in the Grindelwald is 14,000 feet long. The two wire ropes, 1 inch in diameter, one for the loaded truck, the other for the empty, hang without a support at an angle of about 26 degrees. The trucks consist of two connected wheels running on the wire rope, the single logs being attached by hangers. A single rope running over a drum is used to regulate speed and return the trucks. The longest of these wire rope tramways in use is five miles long.

Log Loading Machine—Loading Logs from the Yard on to Cars, which are Placed by the Loader.

The portable railway was first devised in 1876 in France by Decauville for farm use, but has found, in much improved form, adaptation and wide use in German forests, usually in connection with more permanent roads. The portable portions are laid on the ground without any, or with little, road work, each section consisting of two rails attached to steel ties of shallow trough pattern with a 24 to 30-inch gauge; each yoke 6 to 15 feet long, with a 10 to 24-pound rail, weighing 75 to 100 pounds, so that one man can carry it; a simple link device connects the single yokes. A 9-foot yoke with a 15-pound rail on 3 iron ties costs about $2.50. For locomotion animal or steam power is used, or else gravity. If horses are used they walk not between, but beside the rails.

The objection to this light railway is that it usually requires a reloading at the main standard gauge track. Where, however, this can be avoided, or has to be done anyhow, or when hauling to rail becomes necessary, the use of this portable railway may recommend itself in localities of more or less plane or slightly rolling topography, where enough quantities have to be moved considerable distances, and hence the hauling on roads becomes expensive. Where the grades do not exceed 5 per cent, a horse may move on such rails, according to grades, from three to six times the loads which it may move on common earth roads, and, if the time element is also taken into account, a horse will be 20 times as efficient on rails as on earth roads. According to financial calculations under German conditions, the portable railway costs, including renewal and maintenance, only one-half of the cost of a good stone road, and slightly less than a loam and gravel road 4 yards wide; while the cost of moving per ton with horse power is, on a 4-mile run, according to grade, from one-third to one-ninth that on gravel, and three-fifths to one-third that on stone roads, the efficiency being, of course, less pronounced on heavier grades than on horizontals.

While the logging railroad is designed to substitute for the long haul by sled or wagon and for water transportation from the woods to market, the transportation from stump to rail, road or water, is still largely done by animal power, although efficient steam skidding devices are in existence. The pioneer of these, the Glover & Chandler Steam Logger, first operated in Michigan in 1887, was a ponderous machine of the locomotive type on sleds, which needed no special road, making its own ice road by introducing the exhaust steam into the four hollow drivers. The logs were loaded on cars on runners, 20,000 feet being a good load for a 5-mile haul on 20 inches of snow. This ingenious machine did not prove itself practical. A similar locomobile device is being used in California in the sugar pine district; in this case on wheels with wide faces and large diameters. Such locomobile methods are applicable only under very special conditions and do not appeal to the forester, as they are apt to smash more young timber than is desirable.

On the other hand, the lately developed wire rope steam skidding systems may be adapted with satisfaction, even for the more careful logging which the forester is to perform. First successfully applied in the cypress swamps of the South, then on the mountains of the Pacific Coast with the ponderous pines and firs, these steam skidding methods promise to supersede the old-fashioned horse and mule wherever large enough masses, especially of hardwoods, are to be lumbered, and where railroads can be profitably employed to bring the log harvest from the forest to the mill.

The Steam Log Skidding Machine, originally patented by Horace Butters, of Ludington, Mich., about fifteen years ago, has been the prototype of the various devices which are now in practice, perfected during the last 10 years by Messrs. Spencer Miller, famous for his device of coaling vessels at sea, and J. H. Dickinson, and are being manufactured by the Lidgerwood Manufacturing Company, of New York. These two engineers have adapted the Bleichert system of rope tramways and the Butters logging and loading devices to the problems of logging in most ingenious ways. Their devices, used in connection with the logging railroad, have brought out more and more the engineering features in the harvesting of forest products.

The present steam skidding system, first suggested by Mr. Dickinson in his thesis of graduation from the Engineering College of Cornell University, relies upon a stationary hoisting engine, and brings the logs from shorter or longer distances to the cars by wire ropes running over drums, the ropes being disposed in various ways according to the lay of the ground.

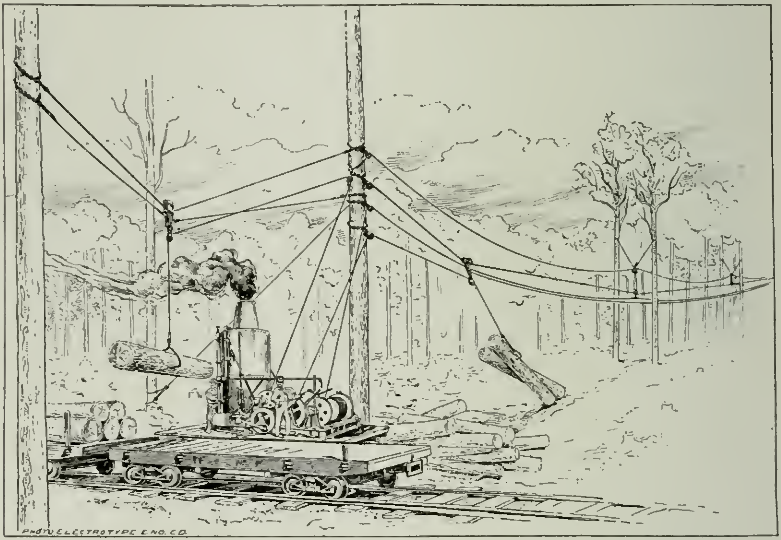


PHOTO ELECTROTYPE ENG. CO.

Skidding and Loading Logs.

There are now four different methods employed. The simplest, which is applicable on such flat lands as the Southern pineries, consists in snaking the logs over the ground and assembling them at the cars by means of a hoisting engine and drum, a horse or mule returning the rope with the grappling hook or tongs at the end to the logs; the loading is done by a separate rope and drum. One of the essential devices in this and all other systems is the cast steel nose (Baptist patent) which caps the log automatically when the rope is pulled taut and steers the log over any stumps, stones or other impediments.

The distance to which this skidding may be done is, of course, dependent upon the length of rope which it is practicable to wind on the drum or drums and to have the horse return. Usually this is not more than 1,500 feet, when the machine may make 140 to 160 pulls per day, the cost on the average being about $24 per day, and the output, of course, dependent on the character of the timber and the log size, which determines the number of feet coming with each pull.

Where the ground is less flat and simple in contour, and where it is preferable to return the rope and grapple automatically, the "slack rope system" may be employed. In this system a wire cable is strung from a head tree near the engine to a stump in the woods, on which travels a carriage (Miller patent), with a specially designed block (Butler's patent) through which the skidding rope with logging tongs works, so as to allow sidewise extension; an outhaul rope, running over a separate drum of the hoisting engine, returns carriage and tongs to the woods, where the tong men pull the rope slack and attach the tongs to the logs lying along the line shorter or longer distances.

The loading on cars is done by a separate set of drums and rigging. To use this system, which may extend to a longer distance than the snaking system satisfactorily, the ground must be tolerably free from rocks and obstructions. According to conditions and distances, from 80 to 120 pulls may be made in a day. A later improvement provides for a number of side lines working simultaneously, by which the efficiency is greatly increased.

In the cypress swamps, where this method is largely used, the machine is placed on a large scow, moving in canals prepared to float the logs. Here the distance to which the skidder works is 2,500 to 3,000 feet, the ponderous logs moving at the rate of 500 to 600 feet a minute, breaking through the timber with thundering noise. Such a pullboat is capable of landing 30,000 to 50,000 feet per day in the water.

In more mountainous districts, where narrow valleys and coves with steep slopes are to be lumbered, the log-gathering system finds its conditions. In this a cable is stretched from slope to slope across the railroad track in the valley, and the logs are gathered to the track by the skidding rope and carriage. The distance to which the system may work, depending somewhat on the degree of slope, may be up to 1,000 feet, when from 120 to 150 pulls per day may be made.

In these last two systems up-hill skidding is, to be sure, as easy, or even easier, than down-hill. According to conditions, either of these systems, or any combination of them, or a combination of skidding by horse and steam, will give the best results.

In forestry work, where the care for the young aftergrowth must be taken into consideration, modification of the methods of procedure will be required. They are, however, directly applicable where clearing with artificial planting is practiced, or where the strip system is used, which consists in clearing strips and securing the reproduction by seeds from the neighboring old timber which is left standing. When the forester shall be a fully recognized and established institution in the United States we may expect that he will develop these methods of exploitation to suit the additional requirements of silviculture.

In mechanical engineering, also, there is still a wide field unoccupied, the development of which would aid the business of the forester. We are still relying on brute force for felling trees, sawing them into logs and cutting and splitting cordwood. Attempts to apply steam or electric power in tree felling have so far failed to bring out any practical method. There are now on trial cordwood cutting machines, but they are so far only applicable for very special conditions which can be rarely met.

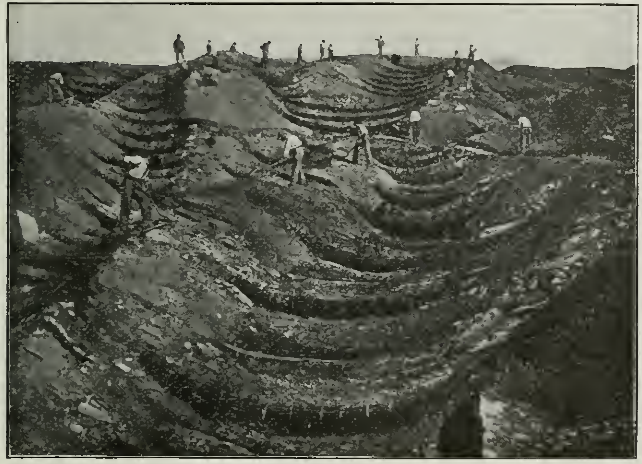
In entirely different direction is engineering skill demanded, and a special line of forest engineering has developed in connection with the reclamation and reforestation of sand dunes and denuded mountain sides. This has been especially developed by the French foresters, the French government having spent many million dollars in covering the lands and sand dunes of Gascony, and in safeguarding the Vosges and Southern Jura against torrential action induced by deforestation. This forest engineering is now practiced

Showing Torrential Action in Valleys.

in all countries where forestry is developed and the necessity for this work has been recognized.

The fixation of sand dunes has also been begun in the United States by the Harbor Commissioners of Massachusetts at Cape Cod and elsewhere. It is a simple operation, which consists in first quieting the sand by mechanical means, fences and brush, or turf cover, and by cutting off or breaking the force of the wind by means of an artificially induced forward dune. Then grasses and other deep rooting and root-creeping plants are used to bind the sand together, and finally tree growth can be established to give permanent protection.

On the denuded mountain slopes it is also first the mechanical quieting of water and soil movement which must precede the work of the forester. This work must begin at the top of the mountains, where the waters gather their momentum into torrents which carry soil and debris to lower levels. By fascine works, revetments and retaining walls the waters are obstructed in their direct descent, and the violent rush over steep slopes is changed into gentle falls, when the pockets behind the breastworks are filled up with debris and soil. Then, when the waters are directed into proper channels and the soil has thus become quieted, sodding and sowing the grass restores the meadow on the gentler slopes, while on the steeper slopes a forest growth is planted and the equilibrium of nature's forces, which man had disturbed to his own detriment by the reckless devastation of the mountain forests, will be gradually re-established.



The Use of Fascines to Stop the Erosive Action of Water.

These glimpses into the problems of an engineering character which are presented to the forester will suffice to justify the claim that he is in need of a considerable amount of engineering knowledge and gumption, which is to be applied under conditions in which it is not usually practicable to employ an engineer.

While for main constructions it may be advisable to call in an engineer, at least in consultation, in smaller constructions and in operating roads, railroads, etc., the forester can hardly afford not to be his own engineer. He must have the knowledge which will make him independent of the professional engineer. Students of forestry, therefore, need a course in engineering which will make them acquainted with principles and methods of construction of special interest to them in their business. On the other hand, engineers may find a field in solving engineering problems for the forester, and in improving his methods, without becoming a professional forester.

The Winter's Harvest—Banking the Logs, College Forest, N. Y.

Time fails to discuss another relationship between engineer and forester, in which the engineer is dependent on the latter as a producer of one of the important materials of engineering. The engineer has largely failed to comprehend the nature and applicability of this material, and has misused it often because he lacked the knowledge of the forester regarding it. The science of wood, timber physics, which forms a branch of forestry knowledge, as it teaches the characteristics and the causes of these characteristics of the forest crop, this science, so far only poorly developed, although wood has been used so long, is indispensable to the intelligent engineer. Even though wood, in engineering work, has been largely displaced by stone and iron, it will nevertheless be always needed, and when it is learned not only how to select and inspect it for different uses when grown, but how to produce the desired qualities whlle growing, the forest engineer will have fully earned his title.

DISCUSSION.

Mr. L. E. Cooley—What is the extent of the Adirondack reserve? What is the state of New York proposing to do in that Adirondack country?

Prof. Fernow—That is what we would like to know ourselves. The Adirondack, so far purchased and owned by the state, comprises about 1,500,000 acres. The desire is to secure the majority of about 3,000,000 acres. About $2,000,000 have been spent so far in the purchase of this property. This year the Forest Preserve Board had been very modest and asked for only $200,000 to go on with the good work; but, as you know, we have a very economical governor, and he promptly cut out the appropriation. He says we have been going on long enough buying and first wishes to know what we propose to do with the purchase. We have had a forest commission since 1885 in charge of this property. There is no question as to the propriety of the state buying this property, especially as it is usually taken when the lumbermen have culled the valuable part do not want it any more, but the time for a systematic mangement under definite plans has certainly arrived.

I desire to say that forestry never pays in the beginning. It is an expensive job, and therefore the task we have undertaken with these woods is not an easy one to solve.

Mr. Grant—Is New York the only state which has gone into that work?

Prof. Fernow—New York was the first state to adopt the reservation policy. It happened to own, by non-payment of taxes on the lands, about 600,000 acres. After the lumbermen had stripped the timber the state took the land and could not get rid of it.

The next to follow in the reservation policy was Federal Government which has now set aside fifty-eight (58) forest reservations with over 40,-000,000 acres in the western mountains; not the finest timbers, not always forest lands, but large tracts of land have been thus withdrawn from sale, and some policy regarding their management is now gradually developing.

Then came Pennsylvania, where two years ago legislation was passed to establish state forest reservations. First, only three reservations of about 40,000 acres were called for, and now the Forest Commission has the right to bid in any lands that come in for sale on account of unpaid taxes, and there are other provision for enlarging the state holdings.

Then the state of Michigan is beginning to move in that direction. A most excellent law was before the legislature of that state last year, providing for the reservation of certain cut over lands but the farmers objected to it, because if the state should withdraw these lands, no poor settlers could be induced to take up these lands and help pay the taxes. Nevertheless, at the last moment, I do do not know exactly how it came about, but within the last two or three weeks 57,000 acres have been given to the forestry commission of Michigan and others will come in time, so that we have now three states entered upon the forest reservation policy.

Mr. Randolph—Did I understand you to say that Cornell has 50,000 acres?

Prof. Fernow—Cornell has 30,000 acres which were purchased by the state and given to Cornell for the purpose of demonstrating methods of forest management, so that we are not allowed to preach only,—we have to practice.

Mr. Randolph—What varieties of timber are there in this forest?

Prof. Fernow—It is a hardwood forest. The Adirondacks contain mostly maple, birch and beech, with originally spruce and white pine. The pine was all culled out about thirty years ago; and the spruce has also been largely culled out. Other species are present, but the three mentioned hardwoods are our main crop. Hardwoods have never been logged in the Adirondacks to any extent.

Mr. Randolph—Do you have chestnut wood there too?

Prof. Fernow—No; we are 1500 feet above sea level; that accounts for their absence in our latitude.

Mr. Cooley—Are there no other reserves in the Adirondacks?

Prof. Fernow—Yes, private for game; a large number.

Mr. Tratman—We all take more or less interest in our forest resources and admit that they need protection, but I am afraid we are not very practical or energetic in our intesest. There can be no doubt that something ought to be done, and without delay in regard to protecfing our forests and reforesting. There is much talk about what should be done, but in the meantime the forests are being burned and destroyed at such a rate that the outlook for the future is somewhat gloomy. Although Prof. Fernow has shown that several of the states have made a beginning, it seems to me it is a question whether by the time we get really started on any practical system will there be any forests left to preserve.

I was up in Michigan, a week ago, right in the heart of what was once the forest country, but not only is the timber gone but conditions are such that for large areas any reforesting is an impossibility. The timber—first, second and other growths—has been cut and burned and then burned over again until there is not even brush left, and the unprotected soil has been destroyed and even washed away until nothing but rocks and boulders are left. Reforesting under such conditions is an impossibility but our forests should be so protecteced and cared for that such conditions cannot occur. In that same country they are establishing a reservoir for one of the new stamp mills. Part of the watershed has been denuded, but the mining company is making it its policy to improve the remainder and preserve what forest there is, recognizing that when the trees are gone there is nothing to hold the water. By proper administration the company also expects to obtain a permanent supply of cordwood, etc., from this watershed.

What we want is some means of extending the work of the states very much more rapidly. It is a most difficult problem, because everybody's hand seems to be against the forester. We must make a beginning sometime if we are ever going to have any forests.

Prof. Fernow kindly referred to the question of steel ties. I presume that he did that as a little joke on me. I wrote two detailed reports on that subject, and was rather enthusiastic at the time. The second report came out in 1895. I rather expected that these reports would create a little interest among railway engineers, but I am very sorry to say that the only people who displayed any enthusiasm in the matter were inventors. Even now I occasionally have a letter from an inventor whe speaks in glowing terms of my report and tells me he has something that will beat everything I ever described, will last longer and be better in every way. I have had a good many inquiries from engineers and forest men abroad, but in this country the inventor of steel ties is the only man who seems to take any interest in it, although before the formation of the new steel trust one of the large steel companies commenced an investigation.

Mr. Cooley—Can you tell us anything about the influence of forestry on rainfalls and on storms?

Mr. Fernow—I gave a lecture on that subject to-day and if you had been there you would have been disappointed.

We have been discussing that question for the last one hundred years trying to find out the actual truth, but we have to confess that, owing to inability to devise instruments of measuring, we have not been able to come to a conclusion. In other words, the influence of forests on the climate is something that can at present only be deduced by philosophy and not by scientific methods, and especially about rainfalls we know the least, for the reason that a rain gauge has not yet been invented which will measure within 40 per cent of the truth.

If you will permit me I will add a few words to Mr. Tratman's remarks regarding forest preservation. The forester does not want to preserve the forest; he wants to cut it down, haul it away and use it; then he wants to reproduce it. Our problem is not to preserve our woods, we want to reproduce it, and that is the problem of the future.

Mr. Tratman—I did not mean to say we simply want to preserve what we have; but if we burn down and cut down indiscriminately and do not adopt means to protect the forest growth or the ground, we cannot reproduce. We want to cut such timber as is ready to cut, protect such timber as is not yet ready, and take steps to reproduce what has been cut.

CXXIX

ONE CENTRAL RAILWAY TERMINAL FOR CHICAGO.

BY R. C. SATTLEY, M. W. S. E.

Read May 22, 1901.

On the transportation facilities of a city depends its growth. By convenient methods of transportation great numbers of people are daily enabled to congregate for business or pleasure in one locality. Next to the food on which we exist and the homes which shelter us, there is nothing on which we are more dependent than on means of transportation. At present the most perfected means of transportation are railroads operated by steam or electricity. Without these means of transportation all large cities would be confined to the seaboard or navigable streams; the Chicago of to-day would not exist, and the dream of the Columbian Exposition in Chicago would never have been realized. In this city, built by railroads to become the second in population on the American Continent, and the greatest railroad center in the world, it would seem most fitting that we should find perfect railway terminals. This can hardly be claimed for Chicago.

Purely from a desire to illustrate the possibilities of handling all Chicago railroads in one terminal, I have given some study to a plan which would not only furnish complete facilities in one grand central terminal station for every steam railroad entering the city of Chicago, but would eliminate all grade crossings within the terminal territory.

The natural advantages of Chicago for railway terminals make it possible to have one of the most convenient central stations possessed by any city in the world, and one that would give to each and every road in the city an equal advantage in terminal facilities.

The location of the present terminals has been determined by the effort of the different corporations to push into the heart of the city. The result has been a great expenditure of money, and that a great amount of the city's territory has been bought by the railroads and used for terminal purposes. In reaching their respective terminals, the railroads form a network of crossings in the heart of the city which the spider would blush to imitate. *At one point alone* nearly twenty acres of solid tracks are required for the crossings and shifting yard which this condition necessitates.

The railroads in Chicago are likely to undergo a great change within the next few years, and already we are reading accounts of various roads submitting plans to be accepted by the city, in order to meet the demands for the public safety. To meet this want, a plan should be formed that will change as little as possible the general entrance to the city of the roads affected by the change, diverting them from some point as they approach the center of the city to a few great arteries, which shall be elevated, or pass over subways or under viaducts, or part elevated and part crossed by viaducts and subways, and run these all into one terminal station, to be located at the most advantageous point for all, and at the same time at such a point as to relieve that business part of the city by throwing upon the market the territory which legitimately belongs to the business district; and at the same time at such a convenient distance from the business center as to accommodate better than at present the suburban and city passenger business, and the through and transfer business.

To make clear the requirements of a terminal station to handle the business of all the roads entering Chicago, it will be necessary to present in a tabulated form the business done by these roads, individually and collectively, and below will be found a table showing this information:

STATEMENT SHOWING NUMBER OP TRAINS ARRIVING AND DEPARTING AT THE VARIOUS R. R. STATIONS IN THE CITY OF CHICAGO.

Corrected to September, 1900, from Official Time Cards.

Name of Terminal	Name of Road.	Local and Through Trains		Suburban Trains.		Total Number Trains.	Total Number Sub. Trains at Each Station.	Sub. Trains Percentage at Each Station.
		Ar.	Dep.	Ar.	Dep.			
Wells St.	C. & N-W. Ry.....	18	20	103	108	249	211	28.4
Union ...	C., B. & Q. Ry...	12	12	38	39	101		
" ...	C., M. & St. P.....	10	12	30	28	80		
" ...	P., C., C. & St. L..	5	5			10		
" ...	C. & A............	6	6	4	4	20		
" ...	P., Ft. W. & C. Ry.	7	7	5	5	24	153	20.6
Dearborn	C., I. & L.........	5	5			10		
"	C. & E............	4	4			8		
"	Wabash	8	8	7	7	30		
"	C. & E. I..........	5	5	12	13	35		
"	C. & G. T.........	4	4	5	5	18		
"	A., T. & S. F......	5	5	1	2	13	52	7.0
Central ..	Ill. Cent..........	12	13	110	110	245		
" ..	Big 4............	3	3			6		
" ..	Wis. Cent.........	5	5			10		
" ..	Mich. Cent........	12	11			23	220	29.5
Gr. Cent.	C. T. T. R. R.....			7	7	14		
"	Grt. Western	3	3	3	3	12		
"	B. & O............	4	4			8	20	2.7
R. Island	C., R. I. & P......	8	9	30	30	77		
"	N. Y. C. & St. L..	3	3			6		
"	L. S. & M. S......	8	7	14	14	43	88	11.8
		147	151	369	375	1042	744	1.000

From a glance at the preceding table it will be seen that the passenger business is of two kinds—*suburban* and *through* or *transfer business*. We will speak first of the suburban business, and later take up the through or transfer business.

From the table above it will be noticed where the suburban business is done, and for comparison we repeat them below:

Station A	Chicago & Northwestern Depot	28.4%
" B	Union Passenger Station	20.6%
" C	Rock Island Depot	11.8%
" D	Grand Central Depot	02.7%
" E	Dearborn Station	07.0%
" F & G	Illinois Central Station	29.5%
		100.0%

With stations so scattered over the business part of the city, it is natural to suppose that the amount of suburban and city business done at the several stations is an indication of the suburban and city territory reached by the several roads. The percentage shows us that Station (A), Chicago & Northwestern Ry., and Station (F & G), Illinois Central Ry., do 57.9 per cent of this business, divided as follows: Station (A), 28.4; Station (F & G), 29.5.

This would indicate that the present location *for this kind* of passenger business is fully met by the present location of these two roads, which are located away from the business district, and are yet near enough to fill the wants of the city and suburban residents.

As to the suburban business done by the other four (B, C, D and E) stations, three (C, D and E) of which, by their location, are occupying property which it would appear is too valuable for station grounds and sheds; the other (B), by its cramped quarters, as well as two (C and E) of the others, is entirely inadequate to handle the business required of them in a city like Chicago. It would appear that one station might be found where all the suburban business of these four (B, C, D and E) stations could be handled in one, and yet be located as near the business center as the Chicago & Northwestern Ry. (A) or the Illinois Central (F and G), and thereby give to each road coming into Chicago an equal advantage. Truly, such a solution of the suburban business could not help but give each road an equal advantage, and would work no hardship upon any of the roads by change of location, which change of location is desired to relieve business property which is too valuable for use as train sheds and railroad tracks and should be in the market for business blocks.

Next, taking up the through business handled at the six stations (A, B, C, D, E and F). Anyone who frequented the Chicago stations during the Fair period can form his own conclusion as to the manner in which the business was done. Even in the best conducted and most commodious stations, suburban passengers intermingled with through passengers and through passengers with suburban passengers. Incoming and outgoing passengers met in the same passage to and from their trains. Trains were delayed in going out on time on account of the manner of handling coaches, often being obliged to wait until empty trains backed out of stations to give track room for outgoing trains to back in to load passengers.

Not one station in Chicago has a conveniently arranged baggage-room for discharging or taking on baggage for trains, and some of the newest stations would be the last to copy in their arrangement for handling baggage, express and mail. Such are some of the many difficulties in the manner of handling trains and people under the present Chicago terminal station arrangement.

Another, and the worst complication of the present system, is the transfer business. Under the present conditions, there being six terminal stations, there are five complications of passenger and baggage for each through or overland train arriving in Chicago. These five complications necessitate one or more passenger busses to leave for five different stations; these are followed by five or more baggage wagons to the same stations. Suppose that a through train arrives at each of the six stations (which occurs every day) about the same time. The case then is that thirty different complications arise with both passengers and baggage, and this is leaving out the matter of the complications of mail and express, and extra carriages and hacks that transfer passengers in addition to transfer busses. The peculiar feature of this transferring is, that in passing from one terminal to another the business and most crowded part of the city is crossed by these transfer busses, baggage wagons, express and mail wagons, hacks and carriages. This condition could only be worse by having a greater number of transfer passenger stations.

The remedy for these many complications it is here proposed to offer in a grand terminal station. A station to fill all these requirements must—

First—Be so located as to be approached by wide and commodious streets and avenues for reaching and leaving the station, and command an additional space *for the exclusive use of the station*, so that in times of receptions of political, military or national demonstrations such space, together with the streets in front of the station, should be able to accommodate at least 100,000 people with comfort.

Second—Be so arranged as to eliminate *all* grade crossings both in the station and approaching it.

Third—Be so located as to accommodate all the roads entering

Chicago, and of such capacity as to accommodate all which may in the future wish to reach this station by leased privilege over existing tracks.

Fourth—Be so located as to relieve all the business part of the city of tracks, depots and train sheds, and at the same time not so remote as to be too far from the business center.

Fifth—All trains should discharge their passengers in such a manner that incoming passengers cannot come in contact with outgoing passengers, and that through passengers cannot come in contact with suburban passengers, or suburban passengers with through passengers.

Sixth—The station should be so arranged with baggage, express and mail rooms as to be able to take care of all this matter without delay to incoming or outgoing trains; at the same time such an arrangement that the baggage, express and mail be in separate parts of this room, and each road's business be separated from every other road, both for incoming and outgoing matter. Also arranged in such a manner that all transferring of baggage, express and mail could be done in this one baggage-room or combination of rooms, and each road provided with a track for baggage, express and mail cars to be unloaded and loaded for outgoing trains.

Seventh—The coach yards to accommodate this station should be separate for each road, so that each road in handling its trains cannot come in contact with coach yard of other roads, or with coaches in going to or returning from coach yard, and each yard so arranged that a train switching in yard would not be in the way of a train of empty coaches either going into the yard or going out of it.

In addition to having a station to fill all these requirements, it is here proposed to accomplish these results with dispatch, and a plan of such a station would fill the following requirements:

To be capable of sending out a passenger train every twenty seconds for three consecutive hours, and at the same time these trains are going out, to be capable of receiving a train every thirty seconds for the same space of time; and these results accomplished with ample time to unload baggage, express and mail from incoming trains, and take it on for outgoing trains, allowing the same percentage of trains to handle baggage, express and mail as at present handled by Chicago trains. This is also allowing not only the same per cent of baggage, express and mail cars to be set out and taken on as at present are set out and taken on by Chicago trains, but providing also for future growth.

The transfer of baggage, express and mail matter to be accomplished with the following dispatch:

A car of baggage, express or mail for transfer coming in on any one of the twenty-two roads, and containing baggage for the other twenty-one roads, after being unloaded on the baggage platform of any road, in twenty minutes would be loaded in baggage, express or mail cars on the other twenty-one roads, ready to be taken out. The reverse of this also being true; baggage, express or mail coming in on twenty-one different roads, could all be delivered to the twenty-second, the remaining road, in the same time.

Baggage for city delivery be in place to deliver to teams in fifteen minutes from time unloaded on platform, or baggage received from city be in cars ready to go out in the same time. Express for the city be in its home or city general office in ten minutes from the time it is landed on receiving platform, or in cars ready to be taken out in twenty minutes from time it leaves express office. Mail matter received for Chicago be delivered at the post-office in twenty minutes from time delivered on platform, or in cars in the same time after leaving post-office for outgoing mail on any or all of the Chicago roads.

In the plan for a proposed station to accomplish these results we would be specific; not only designating where each road comes into the station, but would propose to prove by an example the truth of the possibilities claimed for the station. By "the possibilities" is meant the every-day working capacity of the station, and the assertion is ventured that with as good management as shown by Chicago roads for the six months of the World's Fair, the proposed station could be worked to receive or send out a loaded train every ten seconds for three consecutive hours, three hundred and sixty trains an hour, though this would run trains two and one-half minutes apart on the same track in leaving the station. However, the proposed working capacity of the station would be to run out one hundred and eighty trains an hour, and run them five minutes apart on the same track, or the same as the Illinois Central's regular suburban business is at present run in the busy times of day. This proposed spacing of trains would make the capacity of the new station fifteen times the capacity of the Illinois Central regular suburban business, and answer all the future requirements of the City of Chicago.

There are many other results that might be accomplished by the proposed arrangement of all the roads in one terminal station, but they will be referred to in the explanation of the map and station arrangement setting forth this information, also the location of a freight yard and river slips for each road, with the manner of handling them; and last, a projected loop to accommodate the four elevated roads reaching the business district, so as to complete the entire matter of handling people. And any person taking any one of the elevated roads in Chicago would land at the Grand Terminal Station, or from the Grand Terminal Station step onto elevated cars and land at any part of the city reached by elevated roads. The business district also reached by an elevated loop, and a tunnel loop extending around the business territory.

It will now be my object to show a design to accommodate all those roads in "One Grand Terminal Station," and illustrate how it would fill the requirements.

I appreciate the difference between an article calling attention to the shortcomings of existing conditions, and one showing a design to eliminate all these objectionable conditions. It is easy to criticise, but not so easy to do better than those we criticise. It is only a matter of a few hours to write an article pointing out the faults of the present terminals. It has been a study of some years to prepare the design of which this article is the subject and explanation. You can hear daily remarked, "Why don't they run all the Chicago roads into one station?" yet in the sixty years of the city's existence, or rather in that period since railroads began running into Chicago or out of it, no design has been presented to practically or adequately handle in one terminal station all the Chicago roads.

ELEVATION OF TRACKS, OR THE ELIMINATION OF STREET AND GRADE CROSSINGS.

On this part of the subject we shall confine ourselves wholly to the terminal station and the freight yards, river slips and coach yards, all of which are a part of the proposed terminal. The terminal in its location and arrangement can receive at its outside limits the different roads either elevated or on the ground. This arrangement has been purposely made to meet whatever arrangement each road shall make with the city outside of the terminal. Each different property becomes a complete subject in itself, and it is outside the present purpose to speak further than of the terminal station. Each property has conditions peculiar to itself, which must be met to fit each particular case, and are subjects to be met by each individual road and the city.

The terminal, as designed, eliminates every grade crossing both for streets and for one passenger track crossing another within the limits of the terminal map. In locating the different roads in the station, care has been taken to bring them in in such a relation to each other that there shall *not be a crossing* of one passenger track with another for the longest possible distance from the terminal station. Where only one road has been shown to occupy a pair of tracks, it is not designed that this will be the limit of the station's capacity, but it is left in the design that in the future other roads may lease (at the option of the road occupying these tracks) station and track privileges of entering the city over some of the present lines, and be sure of finding sufficient terminal facilities.

It may be that some of the roads at present leasing track privileges in Chicago would not feel able to do more than lease privileges in the new terminal station. These could come in over other lines as at present, and by a study of the map it will be noticed *that the present existing conditions are not disturbed*, as the roads leasing privileges from other roads are either located in the terminal station on the same track as the road leased from, or are on tracks adjacent to them. This placing of roads in the terminal does not in any way change the present existing conditions, which may hold as well in the new station as in their present terminals.

The roads that now occupy other terminals are placed in the proposed terminal adjacent to one another or on the same tracks, the only exception to this being those coming into Station B, Union passenger station. As part of these come in from the north and part from the south, they are separated; two of these to avoid crossing are placed side by side in one part of the terminal, and two others side by side in another part, and one by itself in the terminal.

LOCATION AND DESCRIPTION OF PROPOSED GRAND TERMINAL STATION.

(See map and notice all passenger tracks run under station.)

Locate west of the south branch of the Chicago River and directly south of Taylor street, widened to one hundred and fifty feet, and directly east of Canal street, a Grand Suburban Station, fronting on Taylor street, eight hundred and fifty-six feet long and two hundred and fifty feet deep. Directly north of this suburban station, and separated from it by Taylor street, one hundred and fifty feet wide, locate a Grand Transfer Station, eight hundred and fifty-six feet long and two hundred and fifty feet deep, for the accommodation of all through trains, all overland western, eastern, southern and northern trains, and all trains other than suburban trains. Directly south of the suburban station, and a part of it, extend a train shed south to Twelfth street, widened to two hundred feet. This train shed would be eight hundred and fifty-six feet east and west by five hundred and twenty-five feet from the south side of the suburban station to Twelfth street. Directly north of the transfer station, and a part of it, extend a train shed north to Polk street, widened to one hundred and fifty feet. This train shed would be eight hundred and fifty-six feet east and west, and five hundred feet from the north side of the transfer station to Polk street. Directly north of this transfer station train shed, and separated from it by Polk street, one hundred and fifty feet wide, locate a Grand Terminal Baggage, Express and Mail Station, extending from Polk street to Harrison street. This station would be eight hundred and fifty-six feet east and west and seven hundred feet north and south.

Make the floors of these stations twenty-two feet above the elevations of the present tracks now occupying this ground. This will be only about four or five feet above the present viaducts at this location.

We now have in one combination: First, a suburban station with an outgoing train shed and platforms for outgoing suburban trains. Next, a transfer station and train shed, containing platform for all outgoing transfer and overland trains, and a platform where *all incoming trains, both suburban and through trains*, discharge their passengers. Last, and of vital importance, the Grand Terminal Baggage, Express and Mail Station.

Underneath these stations locate fifteen pairs of tracks running north and south, fifteen incoming and fifteen outgoing. Each pair of these tracks forty feet apart, center to center, which allows for a thirty-foot platform between, counting eight feet outside of the centers of each one of these tracks to give sufficient space to put up an iron fence in train shed to enclose each pair of tracks, and then have each set perfectly independent of any other set. Therefore, for each set of tracks we have a space north and south fifty-six feet wide extending through suburban and transfer stations and train sheds, and through baggage, express and mail stations.

The suburban outgoing platform, five hundred and twenty feet long, is thirty feet wide, and is left open only on one side, where suburban passengers take their trains. The other side is shut off from the incoming track by an iron fence. The platform in the transfer and incoming train shed is divided into two parts the entire length. One side of the *incoming platform* is made eighteen feet wide and five hundred feet long; the other side is made twelve feet wide and five hundred feet long; this last to be used for transfer and through trains going out.

Under the baggage, express and mail stations, instead of using the entire space of thirty feet between the tracks for platform, a track for baggage, express and mail is provided the entire length of this station, seven hundred feet. Iron columns are used in or near the center of the fifteen-foot platform, left between the incoming track and this side track, to support the building. The above columns are used here to give platform room; but between each adjacent pair of tracks a three and one-half-foot wall is used the entire length of the building, the construction of the building being such that no harm could come to the building if any of these columns were removed. This baggage, express and mail track comes out of the incoming track at one end of the baggage station and joins with the outgoing track at or near the other, so that a train wishing to set out a car of baggage, express or mail, could simply throw out their cars coming in, or when pulling through under the baggage station, and outgoing trains switch out their cars before pulling into station to take on passengers. Two trains could unload passengers behind a train setting out cars, so there would be no delay on that account. This arrangement under the baggage, express and mail station provides for a ten hundred foot track clear car room, and a platform ten hundred feet long and fifteen feet wide *for each of fifteen pairs* of tracks.

This platform is provided with a suitable number of elevators for baggage, express and mail. The baggage elevators extend to the first floor and land in a baggage room whose floor elevation is twenty-two feet, same as the passenger stations. The ceiling in this baggage room is twenty-four feet high, or at elevation forty-six, and the floor space fifty-six feet wide by seven hundred feet long *for each of fifteen pairs of tracks.*

The mail elevators land all mail in galleries twelve feet above the floor of the baggage room, or at elevation thirty-four feet. These galleries run at right angles to the baggage rooms, or east and west, and a suitable number of these would be provided, and all connected with the platform below with elevators. Part would be used for mail received from station, and part used for mail delivered to station, and others used exclusively for transferring mail so as to secure the greatest dispatch. The transferring of baggage would also be done in galleries provided for baggage only, and connected with platforms by elevators so as to secure the greatest dispatch in transferring baggage.

The express elevators would be designed to land all express matter on the next floor above the baggage room, where it would be designed to locate the city express offices for all the express companies in Chicago.

The baggage rooms, which are located on the first floor of the Baggage, Express and Mail Station, would be connected with the transfer stations by galleries fifteen feet wide, twelve feet above passenger platform, running north and south the entire length of the transfer station train shed, and under Polk street, to the baggage room, and then ascending and landing in a gallery at about elevation thirty-six feet in the south part of the baggage room. It would also be designed to connect these baggage rooms by a multiple moving sidewalk, such as was used at the World's Fair and was used at the Paris Exposition, extending along the north side of the transfer passenger station at elevation about thirty-six feet in the train shed, and around on the east and west sides of the train shed, crossing Polk street at elevation thirty-six feet, fourteen feet above the grade of Polk street, which is twenty-two feet.

This multiple sidewalk to run along the south part of the baggage rooms at the same elevation as the above galleries reached by the galleries through train sheds. People could get off at any number from one to fifteen, corresponding with the number of the station the passenger goes out on or has come in on.

(It would be the design of this station arrangement that all tickets have plainly marked *the number of the road its train goes out on,* so gate keepers can plainly punch, being provided with a punch with his station number; the baggage man also using a punch with a corresponding number with his station baggage room. This numbering of tickets would also be designed for all transfer tickets passing through Chicago, the ticket being plainly marked "Transfer at Chicago to Station No. 1 or 15, or any number between." Conductors checking passengers to Chicago holding tickets going out on other roads, give the passenger a ticket reading "Transfer at Chicago to Station No. —," corresponding with the number the train goes out at, as indicated on ticket.)

It would be designed to receive all baggage from teams or baggage wagons at the south end of the baggage room, and to deliver small baggage at this end. All trunks and heavy baggage to be delivered to baggage wagons for city delivery, being delivered at the north end of baggage rooms.

All express to and from the station to be handled on the west or Canal street side of the station, reaching the express wagons from the express offices, or the express offices from wagons by elevators along west side of station.

All mail matter delivered to or received from the city is designed to be delivered and received on the east or river side of the Baggage, Express and Mail Station, on an elevated drive for the exclusive use of mail, at elevation thirty-four feet, the same elevation as the galleries used in the station for mail matter.

This elevated drive to be reached by crossing Harrison street bridge at elevation thirty-four feet, which after crossing bridge from west to east descends north on Franklin street four feet in one hundred feet to Van Buren street; then by going one more block north to Jackson street and three blocks east brings us to the post-office. This mail delivery and receiving side of the station falls mostly inside the half mile circle from the center of the post-office.

The simplicity of reaching this proposed terminal station with twenty-two roads cannot help but recommend itself to the most skeptical. The accompanying plan, 600 feet to 1 inch, shows each road entering Chicago as it is designed to bring them into the terminal, and an actual projected location with the curves drawn in are shown as stated above.

It is designed to use fifteen pairs of tracks, fifteen incoming and fifteen outgoing, also fifteen coach tracks for sleepers going out (forty-five tracks in all), to accommodate the twenty-two roads. A moment's study of the design will show that *not one* grade crossing of one passenger track with another is made within over one mile of the station. (Great stress should be put on the matter of station numbering in a design of this kind). Each one of the fifteen pairs of tracks is as independent of all the others in its platform and station arrangement, and also its train and coach yard, as if the other did not exist. It is a proposed departure from the general idea of a union station, having all the advantages of a union station and none of the disadvantages, and in its operation as independent as fifteen separate and independent stations.

The location of the different roads in the terminal station is as follows:

Station Nos. 1 and 2—Chicago & Northwestern (l);

Station Nos. 3 and 4—Chicago, Milwaukee & St. Paul (j);

Station No. 5—Pittsburg, Cincinnati, Chicago & St. Louis (w), are reached from the north, coming in along the south branch.

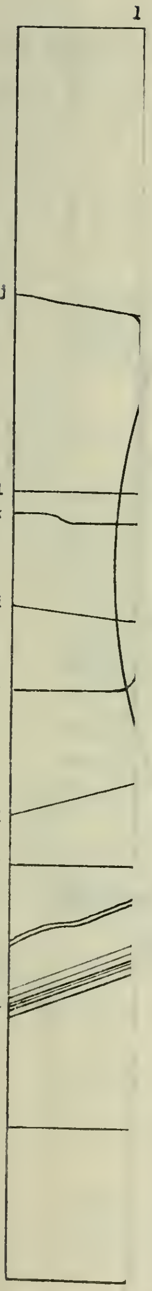
Station Nos. 1 and 2 (C. & N.-W. "l"), is put on the extreme east; it avoids crossing other roads.

Station Nos. 3 and 4 (C., M. & St. P. "j"), is put next, its Evanston branch crossing No. 1 and 2 in reaching the double track of Nos. 3 and 4 in reaching station. This one grade crossing is the only grade crossing of one road with another in the limits of the plan.

Station No. 5 (P., C., C. & St. L. "w"), coming in from the north along the south branch.

$$\text{Station Nos. 6 and 7—}\begin{cases}\text{Illinois Central (q).}\\ \text{Michigan Central (u).}\\ \text{Big 4 (r).}\\ \text{Wisconsin Central (z).}\end{cases}$$

All come in from the east on an elevated double track on the same ground *now* occupied by the Illinois Central track just north of Sixteenth street. This track elevated and crossing the river at elevation sixteen feet above ground, or twenty-six feet above high water, on a new three hundred and fifty-foot bridge (six-track bridge) on the site of present bridge at this point; bridge to swing over land on the west side of south branch, and give one hundred and fifty feet clear channel in the river. This bridge, as well as the others proposed, is divided—two hundred feet on one


1
j
l
k
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c

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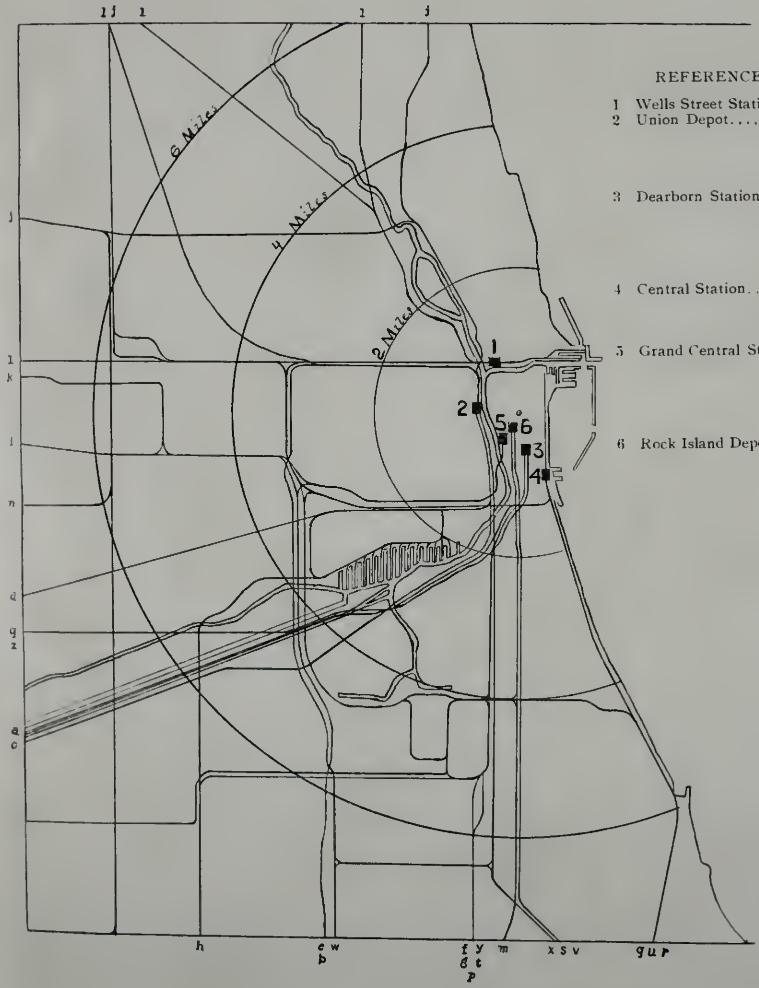
Sattley—Railway Terminal for Chicago.

CHICAGO TERMINALS

Scale 1/10" = 1 Mile



REFERENCES, DEPOTS AND RAILROADS.

1	Wells Street Station	C. & N. W. Ry	l
2	Union Depot	C. B. & Q. Ry	d
		C. M. & St. P. Ry.	j
		P. C. C. & St. L. Ry	w
		C. & A. R. R.	c
		P. Ft. W. & C. Ry.	x
3	Dearborn Station	C. I. & L. R. R.	t
		C. & E. R. R	g
		Wabash	y
		C. & E. I. R. R.	f
		C. & G. T. R. R.	h
		A. T. & S. F. Ry	a
4	Central Station	Ill. Cent. R. R.	q
		Big Four	r
		Wis. Cent. R. R.	z
		Mich Cent.	u
5	Grand Central Station	C. T. T. R. R.	
		Chicago Central	e
		C. & N. Pac. Ry.	k
		C. & So. Western	n
		Chicago Gt. Western	i
		B. & O. R. R.	b
6	Rock Island Depot	C. R. I. & P. R. R.	m
		N. Y. C. & St. L	v
		L. S. & M. S. Ry	s

OLD TER

l ......W
d ......U
j . ....
w......
c ......
x ......
t ......F
g ......
y ......
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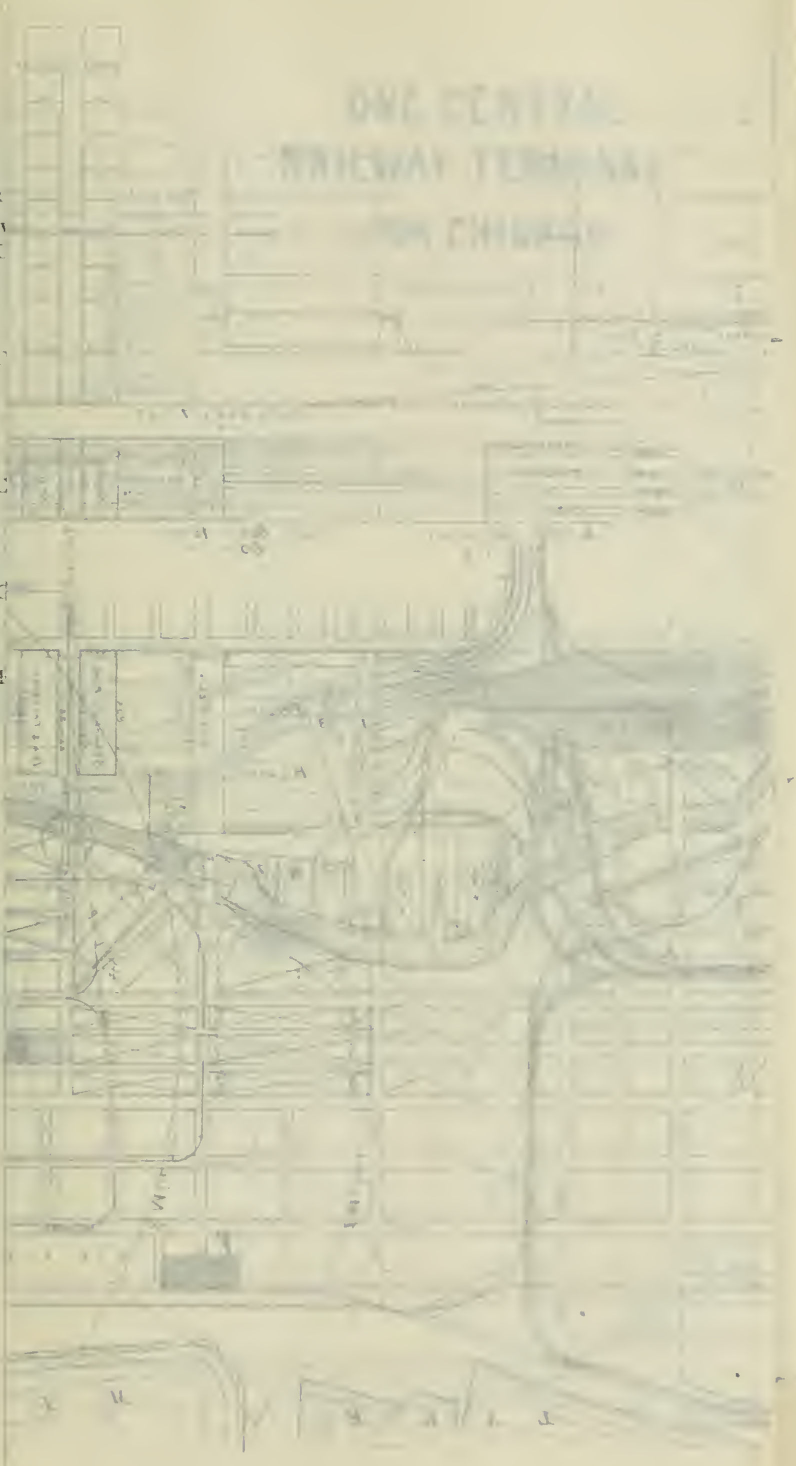

WESTERN SOCIETY OF ENGINEERS.
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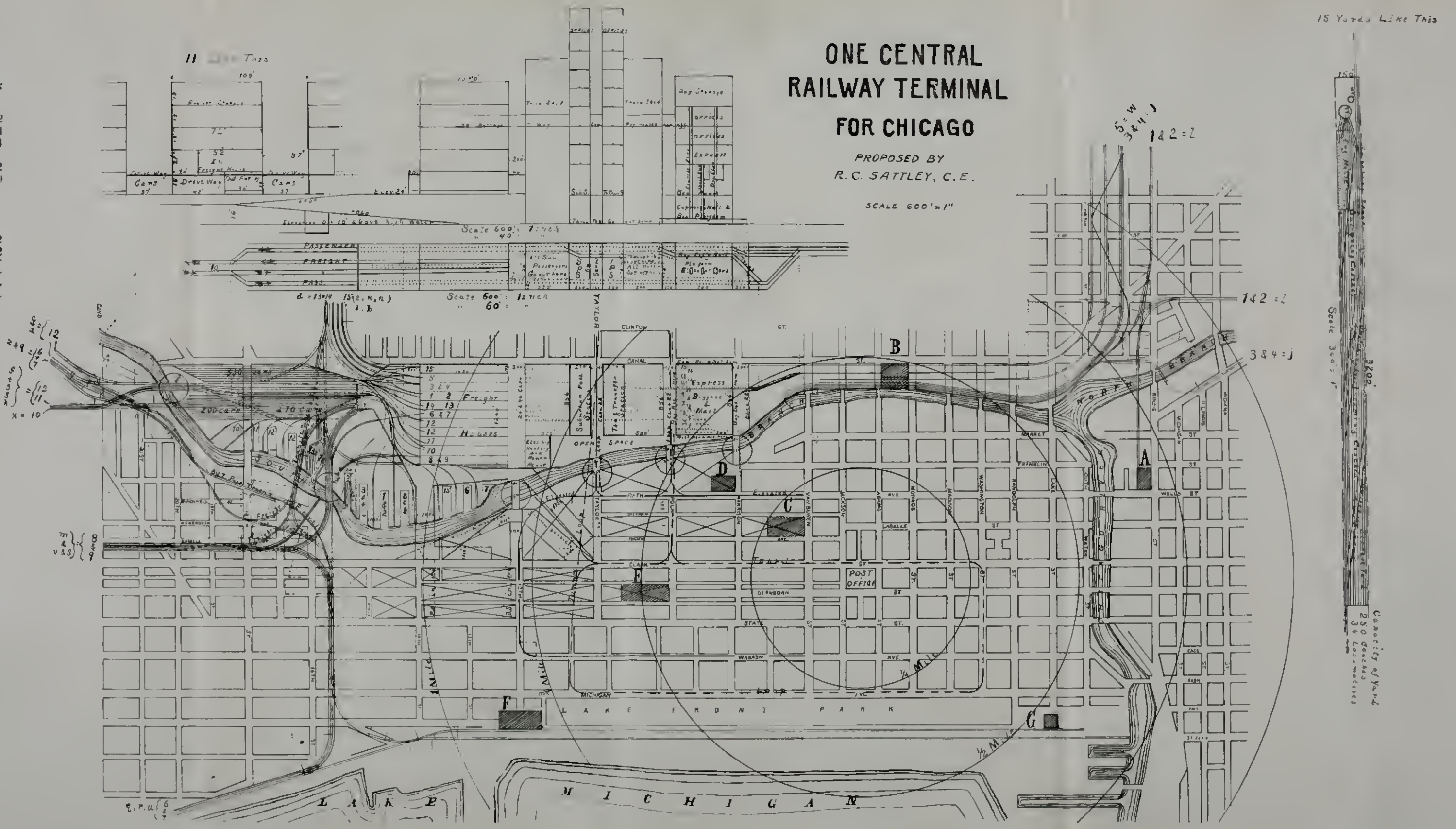
Sattley—Railway Terminal for Chicago.

ONE CENTRAL RAILWAY TERMINAL FOR CHICAGO

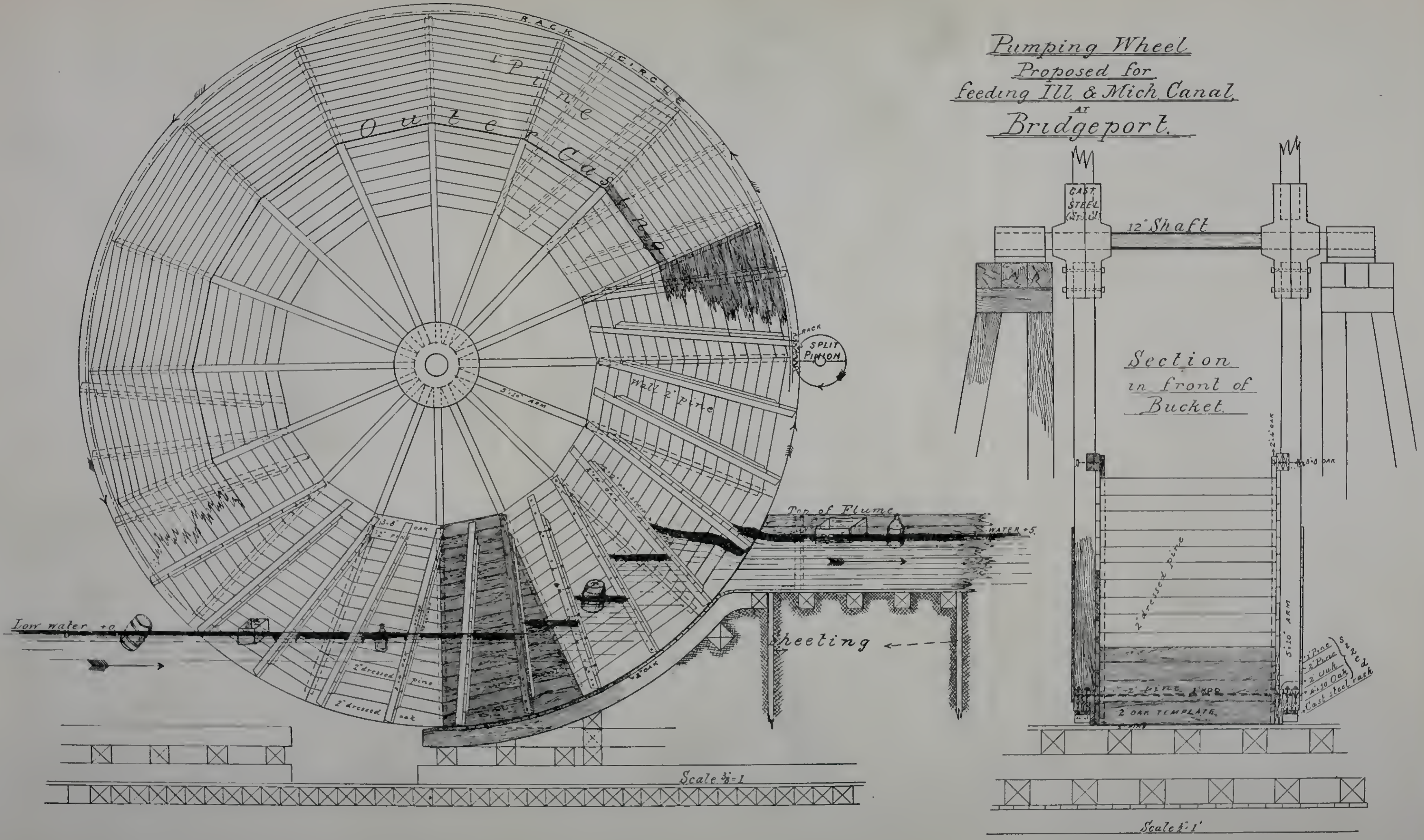
PROPOSED BY
R. C. SATTLEY, C. E.

SCALE 600'=1"

	OLD TERMINAL.	RAILROADS AND LOCATION IN NEW TERMINAL.	
l	Wells Street.	C. & N. W. Ry.	1 & 2
d	Union	C. B. & Q.	13 & 14
j		C. M. & St. P.	3 & 4
w		P. C. C. & St. L.	5
c		C. & A.	12
x		P. Ft. W. & C. Ry.	10
t	Dearborn	C. I. & L.	11
g		C. & E. R. R.	11
y		Wabash.	11
f		C. & E. I.	11
h		C. & G. T.	12
a		A. T. & S. F.	12
q	Central	Ill. Cent.	6 & 7
r		Big Four.	6 & 7
u		Mich. Cent.	6 & 7
z		Wis. Central	6 & 7
e k n	Grand Central	C. T. T. R. R.	15
i		Great Western.	15
b		B. & O.	15
m	Rock Island	C. R. I. & P.	8 & 9
v		N. Y. C. & St. L.	8 & 9
s		L. S. & M. S.	8 & 9



Lo


Pumping Wheel
Proposed for
feeding Ill. & Mich. Canal
at
Bridgeport.
RACK CIRCLE
1" Pine
Outer Casing
RACK
SPLIT PINION
Wall 2" pine
5'×10" ARM
3-8" OAK
2" PINE
Top of Flume
WATER +5.
Low water +0
Sheeting
2" dressed pine
2" dressed oak
Scale 3/8"=1'
CAST STEEL (Split)
12" Shaft
Section
in front of
Bucket.
2'-6" OAK
2" dressed pine
5'×10" ARM
2" PINE
2 OAK TEMPLATE
1" Pine
2" Pine
2" Oak
5"×10" Oak
Cast steel rack
Sized
Scale ½"=1'

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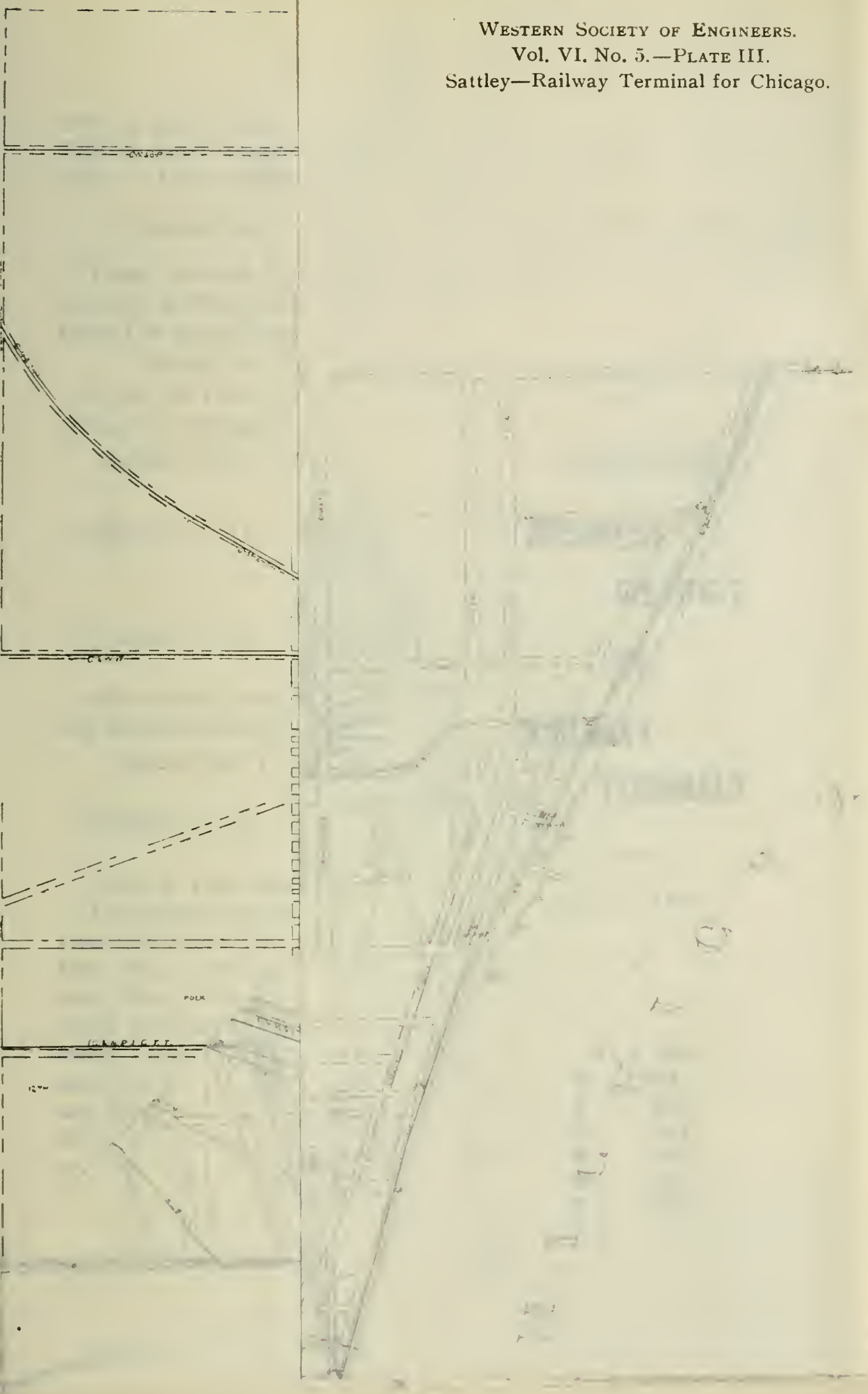
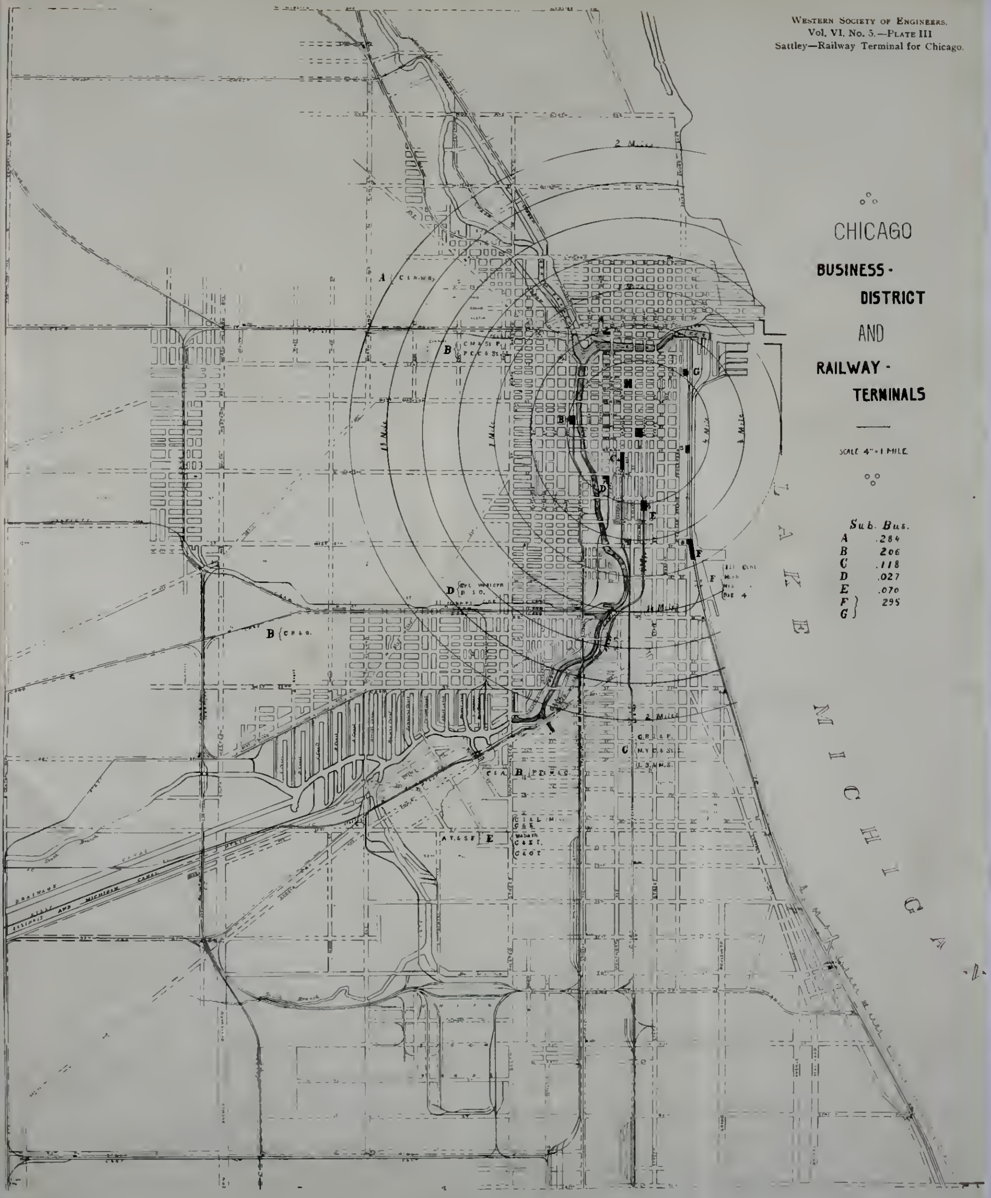
Sattley—Railway Terminal for Chicago.



Western Society of Engineers.
Vol. VI. No. 5.—Plate III
Sattley—Railway Terminal for Chicago.



side of center and one hundred and fifty feet on the land end. This is done to give clear channel one hundred and fifty feet in river. (These bridges should be counterbalanced to swing easily.)

Station No. 8— Lake Shore & Michigan Southern (s).
New York, Chicago & St. Louis (v).

These come in from the south, picking them up near beginning of curve a little north of Seventh street, and swing to the west and cross the same bridge as Nos. 6 and 7.

Station No. 9—Chicago, Rock Island & Pacific (m).

Come in from the south just south of No. 8, swing to left, crosses on the same bridge as Nos. 6 and 7 and No. 8.

Station No. 10—Pittsburg, Ft. Wayne & Chicago (x)—Penn.

Station No. 11— Chicago & Eastern Illinois (f).
Chicago & Erie (g).
Chicago, Indianapolis & Louisv. (t)—Monon.
Wabash (y).

Station No. 12— Chicago & Grand Trunk (h).
Atchison, Topeka & Santa Fe (a).
Chicago & Alton (c).

All come in from the south, over one six-track three hundred and fifty feet draw, same as draw above.

Station Nos. 13 and 14—Chicago, Burlington & Quincy (d).

Station No. 15— Baltimore & Ohio (b).
Chicago & Great Western (i).
Chicago Terminal Transfer (e).

Come in from the west as at present.

The manner of operating the station with the trains coming in from the north (Nos. 1 and 2, 3 and 4, and 5) would differ slightly from those from the south. Space has been provided under freight yard where it is designed to have tracks that will hold about twenty trains for each pair of tracks, so that trains could be made up in coach yard and back down, and in position to pull out as due to leave, at the same time others keep coming in over incoming tracks and fill up as it is emptied. It is not designed to have coach tracks here, only as track space to stand trains on as they come ready to pull out loaded.

The following table shows the names of the Chicago roads. Each road is indicated by a small letter, to locate it on the plan and small map; also shows the proposed location in the new terminal and present location in existing terminal. The last column indicates the number of tracks given in the new terminal and the number of trains in the old, to give a quick comparison of proposed accommodation with present facilities; also number of trains to be accommodated. Note that the location in new terminal of existing roads are on the same tracks or adjacent tracks where they come into the same terminals now, the only exception being the Union Station:

NAME OF ROAD.	Letter Indicating Road.	Location in New Terminal.	Present Terminal.	Number of Tracks Provided in New Terminal.		Number Trains.	
				Pass.	Bag.& Mail	L.&T.	Sub.
C. & N.-W. Ry..........	l	1 & 2	Wells Sta.	6	2	38	211
C. M. & St. P..........	j	3 & 4	Union Sta	6	2	22	58
P., C., C. & St. L......	w	5	"	3	1	10	
Illinois Central.........	q		Central.				
Michigan Central........	u	6 & 7	"	6	2	64	220
Big 4.	r		"				
Wisconsin Central.......	z		"				
L. S. & M. S............	s		Rock Isl'd				
N. Y. C. & St. L.........	v	8 & 9	"	6	2	38	88
C., R. I. & P............	m		"				
P., Ft. W. & C. Ry......	x	10	Union Sta	3	1	14	10
C. & E. I...............	f		Dearborn				
C. & E..	g	11	"	3	1	44	39
C., I. & L. (Monon).....	t		"				
Wabash............... .	y		"				
C. & G. T...............	h		"				
A., T. & S. F............	a	12	"	3	1	30	21
C. & A............	c		Union Sta				
C., B. & Q.............	d	13 & 14	"	6	2	24	77
B. & O.....	b		G'd Cent'l				
Great Western	i		"				
C. T. T., including.......		15		3	1	14	20
Chicago Central	e		"				
Chicago & N. Pacific...	k		"				
Chicago & S. Western..	n		"				
22 Roads.				45	15	298	744

As an example of a train into and through this station: Take a train on No. 10, crossing the south branch at elevation sixteen feet above the ground, twenty-six feet above high water, until we reach a point about six hundred feet north, at which point a switch is put in and the passenger track turns to the right sixteen feet, and after passing the point of frog begins to descend .60 feet in one hundred feet until descending sixteen feet to the ground level, at same point track begins to descend. The track this passenger track switches out of begins to ascend 0.5 in one hundred feet, until reaching elevation twenty-four, the proposed freight yard (to be explained later).

This incoming passenger track, in making its descent, runs under the freight track and under Twelfth street, and comes out into the suburban train shed, in which incoming trains do not stop, passing through under the suburban station, Taylor street, the transfer station, and into the train shed of the transfer station, where trains stop at a platform five hundred feet long, eighteen feet wide. Suburban trains stop near north end, and suburban passengers going to city ascend to Polk street (one hundred and fifty feet wide), or descend to tunnel loop. Passengers going out on other trains, either suburban or through, turn south and ascend stairs into through passenger station, and through to the station they go out on. All through trains stop near south end of platform and passengers ascend into transfer station, and go to the respective through or suburban station they go out on, or to the city, as they may wish. This incoming platform, five hundred feet by eighteen feet, will hold two thousand people (six loaded trains), and people landing on this platform and going out at either end cannot meet other passengers descending to take trains, as only incoming trains stop here and no passengers are taken on at this platform. Suburban people do not pass through station. After unloading passengers, the train pulls through under baggage room and unloads baggage, mail or express cars, all of which is handled as previously described, then pulls out into an open space between Harrison and Van Buren streets, and where incoming tracks join with outgoing. The tracks coming in from the north, 1 & 2, 3 & 4, and 5 (1 & 2, 3 & 4 and 5 take passengers in and out this way), are given a double track for each pair of tracks in station; the others single track, for the short distance of the way.

It will be seen that the design is to have all these tracks run under the street from south of Twelfth street to Lake street, and thereby *not changing* in any way the present condition of this entire territory. It would be a part of the design to replace the viaducts between the south branch and Canal street over all this territory with iron girders, with suitable space to make a water-tight paved floor, and giving all these streets the appearance of perfect streets, so that no appearance of any tracks could be observed in passing over them. The grade of these streets should be uniformly about twenty-two feet above present ground, where tracks are now located. It is the design to have the space open between Harrison and Van Buren from the river to Canal, to afford daylight for switching out baggage, express and mail cars.

Another open space is designed between Washington and Randolph and Canal and the river, where the double track begins again. The six remaining blocks between Harrison and Lake streets it would be designed to build buildings on, and space has been designed to build every fifty feet, C to C, east and west, seven-foot masonry walls (on piles) running north and south between tracks. On these walls erect buildings (walls are used to give stability, should a train ever become derailed and run into the foundation), designed to suit this kind of a foundation.

Next we come to the coach yard. Lying between W. Canal street and Western avenue, and south of C. & N.-W. Ry., is a space occupied by team tracks, freight yards, freight houses, coal yards, round houses, coach yards, etc., etc., crossed by viaducts and cut by streets. It is neither a viaduct district nor the other thing. By the city permitting the railroads to finish this viaduct system, or elevate tracks and put in subways, and eliminating all grade crossings, and by the railroads purchasing an additional strip along the south side of that already owned by the railroads, which strip is mostly unimproved property, this property would make a continuous strip seven hundred and fifty feet wide south of C. & N.-W. tracks to Fulton street on the south. On this coach yards could be provided to accommodate each set of fifteen tracks, with a separate yard for two hundred and fifty coaches each, thirty-seven hundred and fifty coaches in all; engine house for thirty-four locomotives each; turn table, stand pipes, coach repair tracks, and still have remaining on the south side of this strip two hundred feet space north and south by the total distance east and west, where roads Nos. 3 & 4 and No. 5 could locate their freight houses and team tracks that now occupy this territory, approaching them from near Western avenue beyond the coach yards. This location of yards would permit of another convenience.

A suitable boiler plant could be erected to accommodate steam heat for heating all coaches while standing in yards, before being taken by locomotive. Also a gas plant could be erected to supply all coaches with gas. I have drawn a sample of a suitable coach yard fitted to a long and narrow space, and have shown how one could be arranged to accommodate two hundred and fifty coaches, and thirty-four locomotives and turntables, etc., on a space one hundred and fifty feet by thirty-two hundred feet. At the same time easy to operate trains pulling into yard, and engines going to turntable or engine house, out of way of engines coming from turntable or engine house, trains pulling out and switch engines switching in yards.

In the operation of tracks in the terminal station it will be plainly seen how any pair of these tracks could be used in the same manner as the South Side Elevated, previous to completing the loop, by using one extra engine at the north end of baggage room, just north of Harrison street and beyond the north end of baggage room track; these trains understanding to keep out of way of regular trains.

In this manner a train could leave any one of these fifteen tracks every two and one-half or three minutes.

In summing up the passenger business possible in this proposed station, assuming a train to leave each one of these fifteen stations every five minutes, would give us twelve trains leaving each station or pair of tracks every hour, or fifteen times twelve, 180 trains every hour from the Grand Terminal Station. I will also call attention to the fact that as many trains, 180, can come into the station in one hour, and at the same time the others are going out without one person meeting another in ascending from or descending to their trains. I will also call attention to the fact that the above departure of trains from the terminal is fifteen times as many as the Illinois Central sends out in an hour in the busiest time of day. I would also call attention to the possibility of running out trains every two and one-half minutes at the rush hour in the evening, or receiving trains every two and one-half minutes in the rush hours in the morning—360 trains an hour, or a train into or out of the station every ten seconds. This would be accomplished without one passenger train crossing the track of any other passenger train, or crossing any street at grade, or any person stepping onto a track, or any passengers meeting in taking or leaving trains. I think the same results have never been equaled or approached in the history of railroading.

FREIGHT HOUSES, YARDS AND RIVER SLIPS, TO PROVIDE FOR THOSE REMOVED BY THE CHANGED CONDITION.

Roads coming in at Nos. 1 and 2, 3 and 4, 5 and 6 and 7, have freight houses not disturbed by changed conditions, and are expected to handle the bulk of their freight business as at present; but that they may share an equal advantage with all other roads, the freight space has been designed for the business of these roads which come in close competition with other roads. The freight stations, as numbered from 1 to 15 inclusive, are designed to handle the freight business of the roads designated in the table by the same numbers.

There are many peculiar features in the freight terminal arrangements, the extent of which is as follows:

6.50 miles of track at freight houses.
2.18 miles of out-freight houses, 30 feet wide.
2.18 miles of in-freight houses, 52 feet wide.
6.50 miles of freight storage houses, 72 feet wide.
2.18 miles of team drives, 42 feet wide, at out-freight houses.
2.18 miles of team drives, 57 feet wide, at in-freight houses.

The above divided into eleven separate and distinct yards.

Eleven separate and distinct out-freight houses.

Eleven separate and distinct in-freight houses.

Twenty-two separate and distinct team drives to accommodate the above.

The above freight terminal is located on a space 1,050 feet north and south by 1,200 feet east and west, and is so arranged that each road has a separate and distinct accommodation as in the passenger terminal.

The peculiar feature of this freight terminal is that it occupies the ground generally wasted in reaching large terminals. The approaches to the passenger terminal pass under this entire combination of yards, and not one foot of this space is wasted. Remember there is no crossing of tracks under this freight terminal, as no passenger tracks cross one another within a mile of the terminal. Again, there is no crossing of passenger and freight tracks in reaching the terminal. The freight terminal is reached by switching out of the passenger track at the points so indicated on the map. After the point of frog is passed the freight track begins to ascend 0.5 per 100 feet until it rises from elevation 16 feet to 24 feet, the elevation of proposed freight terminals.

At the point freight tracks begin to ascend, the passenger tracks begin to descend 0.60 until descending 16 feet or elevation 0.

Between 16th street and the south branch of the river, and along Canal street, there has been designed two sorting and empty freight car and incoming loaded car yards with a capacity of 800 cars. These yards are elevated so a car can be shifted from them to any one of the eleven freight terminals; one at elevation 24 feet, and the other at elevation 16 feet to 24 feet.

There is a peculiar feature in the manner of handling this freight terminal I wish to call particular attention to. The freight houses are 1,050 feet long, in-freight 30 feet and out-freight 52 feet wide, arranged in two stories. The out-freight house is at elevation 24 feet, and the in-freight house 44 feet, the elevated driveways to in-freight house being at elevation 40 feet. Cars are unloaded onto a system of elevators located in the floors of the out-freight 24 feet high, and elevated to the floor of the in-freight at elevation 44 feet, where it is delivered to teams. The design is to add three or more or additional stories to all of these freight houses, to be used as storage, and any goods not delivered on day received to be put in storage.

It is designed to make these freight houses long (1,050 feet) and narrow (in-freight 30 feet and out-freight 52 feet), to furnish a great number of doors for the delivery and receipt of freight, and save a long truckage from wagon into cars. Only three strings of cars are placed opposite each freight house for the purpose of saving long trucking. I would design to load the same cars to be sent out as are unloaded, not switching them any more than necessary. Any cars not to be reloaded are to be placed near switching end of track, and be pulled out and replaced with other empties as soon as unloaded.

There are many more things that can be said relative to operation of the freight terminal, also the manner of reaching the slips provided for each road; but as they are all shown on the plan, they show for themselves, and can be explained as questions arise calling for an explanation.

The design calls for an elevated loop to the station, a subway under the river to the station, also an elevated walk from the business part of the city to the station, extending from curb to curb of all streets approaching the station, so that the streets can be given entirely to teams and walks to pedestrians.

Such a terminal would be a monument worthy of the greatest railroad center in the world, and would forever remove from the business district of Chicago the objectionable terminals in this territory, and would release for business purposes more than thirty-five blocks of property in the business center of the city. The territory proposed for this terminal is at present used by railroads, and can be used in the manner I have proposed.

The future expansion of the city of Chicago depends upon some such change in its business district. The business property would be increased one-third by this new condition. This advantage to the city would be a lasting benefit to the railroads, and it is in the power of the railroads to bring about this transformation. All the work of track elevation has been in line with this improvement. Now let the railroads do as much for the business district as they have for other parts of the city and we shall then see a Greater Chicago.

DISCUSSION.

Mr. Tratman—I would like to have Mr. Sattley explain where his suburban trains—for instance, the North-Western—would come in and go out.

Mr. Sattley—The North-Western, coming in along the river, would come in and pull through under the baggage room—through No. 1 and No. 2—and out under this freight station where they would have a baggage track. That space will give the North-Western about 250 coaches; also it will give the Chicago, Milwaukee & St. Paul 250 coaches, and the No. 5, P. C. C. & St. L., about 125. That space would only take up on a line with where the North-Western comes in, down to this point here and over to this point. That is as many coaches as come in and require storage in the C. M. & St. P. to-day. I did .not designate this as a permanent arrangement, but it will hold all that come in at the present time directly underneath this freight station.

Mr. Tratman—At 5 o'clock in the afternoon, when you are starting your suburban traffic, you propose to have that filled full of trains and feed them right through.

Mr. Sattley—Yes, that is the idea. Instead of having one circle as you have at Boston, I have fifteen, and there would be no switching. The trains would come right in to the passenger yard where all of these trains stand ready to pull out. There is space under the freight yards for 750 feet. The space is 1,800 feet long and 320 feet wide. This leaves 20 feet for walls, under each space 109 feet, 25 tracks, 13 feet centers, 25 cars each per track; cars 70 feet long, 625 cars for the Chicago & North-Western, 625 cars for the Chicago, Milwaukee & St. Paul, and 85 cars for the P. C. C. & St. L., underneath the freight yard after they pull through the passenger station.

Mr. Tratman—That answers my question. I did not know you were intending to store the trains.

Mr. L. P. Morehouse—The matter of a Union Station in every large city, I suppose, is one that has always attracted more or less attention, but I believe that such stations are not very common, where all the roads entering a city are united in one station. Even if the passenger business is concentrated in one, I think it is very seldom the case that all the freight business is so concentrated. As a historical fact I believe that the matter of a Union Station was talked of fifty years ago in the city of Chicago, when the second road proposed to enter the city. The first road, the Galena & Chicago Union Railroad, brought its track on the west side down to the corner of Canal and Kinzie streets. The Michigan Central was the road which next expected to enter the city, and surveys were made, I know, with a view to arranging a connection with the Galena & Chicago Union road. A survey was made in 1850 and 1851, which terminated at the north at the corner of Canal and 22nd streets, and property was purchased by the Michigan Central Railroad farther north along the line of Canal street, for the purpose of extending the line up to a connection with the Galena & Chicago Union; but when the Illinois Central Railroad was chartered to build in the city, the Michigan Central Railroad abandoned its plan of constructing a line of its own from the Indiana State line, and made an arrangement with the Illinois Central to use its tracks into the city from what was then Calumet, but what is now called Kensington, about fourteen miles south of the city, so that plan never materialized.

In 1855 it was considered desirable that there should be a Union Station of several of the roads, and the Michigan Central, the Illinois Central, and the Galena & Chicago Union, and what is now the Chicago, Burlington & Quincy Railroad, made a contract with one another by which a connection was to be made with the Galena & Chicago Union track on the west side and the Illinois Central Station at the foot of Lake street. It was expected that the track would be built on the north side of the river, crossing the river just east of where the present Rush street bridge is, but that plan was never carried out. A connection was made, however, to accommodate the business of these roads by constructing shortly after that time what is now known as the St. Charles Air Line Railroad, running from the Illinois Central right-of-way near 16th street to the west side of the Chicago river, and over that track those four roads, for some little time, ran their passenger trains to the Illinois Central Station at the foot of Lake street.

That was the nearest to a Union Station that Chicago ever came, I suppose.

At that time I would say that the only other roads entering the city were the Rock Island and the Michigan Southern. I think the Milwaukee & St. Paul road was not built at that time, nor the original Chicago & North-Western road, now the Wisconsin division of the Chicago & North-Western road; so these things have been talked about and this is not the first time the matter has been discussed, but as to bringing all the roads together in the city, I suppose there was not at that early time any serious attempt made, because, as some of you may remember, there was a prevailing opinion in those days that it was not desirable that railroads should pass directly through any city. The people of any particular locality thought it was best for the road to end there, and that the transfer of passengers and freight should be made across the city by teams; that that was what built up a city; made business.

I think I have read in some history of Chicago that, as the other roads came in, there was some attempt made on the part of the press or some other source to induce them to join in a Union depot, but nothing definite was ever done in that connection.

Now, with regard to the present matter, there are one or two questions that come into my mind; one is, what particular benefits are to be obtained by abandoning the present stations of the different roads and centering the business in one?

So far as the conducting of the freight business is concerned, it would seem to me that, possibly, the wants of the city of Chicago are quite as well met by the present distribution of freight houses and freight stations over the city as they would be if that business was centralized.

So far as the suburban passenger business is concerned, the writer admits that about 60 per cent of that business is all very well taken care of by the North-Western and the Illinois Central. Now, whether the other 40 per cent would be better served by taking it from the Union Station on Canal street, and from the Rock Island and Lake Shore roads at Van Buren street, the Dearborn Station at Polk street, and the Grand Central Station on Harrison street, down south of 12th street on the west side of the river, is a question with me. I would say that the suburban service would not be improved by being diverted to this new point. It seems to me it matters comparatively little where other trains discharge their passengers in the city, so far as people stopping in the city are concerned. Wherever they are landed it is going to be somewhere within a reasonable distance of the center of the city, and people will take carriages to their hotels or go to their residences by means of the ordinary methods of communication, so that really the only advantage to be derived from a Union Station is in the case of passengers transferring from one road to another. For instance, a passenger arrives from the south by the Illinois Central and desires to continue his journey to St. Paul by way of the Chicago, Milwaukee & St. Paul; he is obliged to transfer from one station to the other across the city; and so with other passengers on other roads. I can see that it would be a great convenience if that transferring could be done away with, but it is a question with me whether any very large expense would be warranted to bring that about.

There is also the question as to what this would cost. Engineering is a question of dollars nowadays. I believe the engineer is ready to do anything so long as you give him enough dollars, and so in this case it would be a question of dollars. Who is going to pay for this change? The railroads, I suppose. I take it that the railroads would dispose of their property for some other purpose, and and use this money to purchase other property for making the necessary changes. I doubt very much if the managers of the roads terminating in Chicago would, at the present time, seriously consider a proposition of that sort.

As to the statement that the property at present used for railroad purposes in the city of Chicago is more valuable for other purposes, I have an opinion of my own as to that, but I would like to have the opinion of real estate experts as to whether that is a fact or not. My own opinion is that the property so used is not necessary or desirable for other purposes, and I would ask what would be done with it. As I go about the city of Chicago I see a great deal of property which it seems to me there is very little use for, and why it is desirable to bring all this railroad property into the market for ordinary business and other purposes, I do not now see.

This is one of the things on which I would like to have more information.

As to the present necessities of the different roads for this property which they have, I am of the opinion that there is not one of them that would be willing to part with any of the real estate it has in the city of Chicago. My observation is that every road feels the necessity every year of increasing its terminal facilities by the acquisition or the improvement of more real estate in the city, and it would be very difficult to get any of the roads to part with any of their real estate which they are occupying at the present time.

Mr. G. H. Bremner, (C., B. & Q. R. R.)—This has been a very interesting subject to me, and Mr. Sattley's able paper shows much study. I am quite familiar with the locality in which he locates his Grand Central Terminal, and, as he says it is given over—a great deal of it—to railroad property. There are, however, some very large industries which it would be necessary to take possession of—the Chicago Sugar Refinery, four large elevators, the Crane Manufacturing Co., and a number of others, to obtain which would cost an immense sum of money. The fact that a greater portion of the property is given over to railroad uses already—for the same use, practically, to which it would be put by Mr. Sattley's new plan—would indicate that he has not room enough in this vicinity to locate this Grand Central Terminal. Out of curiosity I figured up the area of our freight houses in Chicago, and I find that the floor area of the freight houses which we have is more than double the area which he has allowed for the C., B. & Q. freight houses, freight house tracks and team tracks combined. We are probably now using in this immediate vicinity for these purposes some five or six times the space he has allotted us.

The idea which is advanced for handling freight on two or more floors in a freight house would hardly be acceptable to the railroads, for the reason that it would add so much to the expense of loading and unloading freight. The addition of a few cents per ton for handling freight through the freight houses is a very serious matter on the large amount of freight handled by the Chicago railroads, nor would additional stories added to the freight houses provide for the congestion of streets by teams and of freight tracks by cars, which would be inevitable under the proposed plan, and is even now burdensome.

I think there was in the neighborhood of a couple of miles of dock frontage allowed for by Mr. Sattley's plan. That would be a very small matter divided up among the various roads of Chicago. Our own road owns over 2½ miles of dock frontage and some other roads own more than that.

Mr. Sattley has widened the street to 150 feet. This will not begin to take care of the travel, either passenger or freight. Every morning Adams and Madison streets are nearly filled with passengers from the Union Depot, which accommodates about one-fifth of the suburban service. If we were to congest all the suburban service into one or two streets 150 feet wide, I can imagine how it would be every day, from my experience on Chicago Day, in 1893, on the Van Buren street viaduct, when I could hardly breathe for the crowd.

In regard to the necessity for a Union Depot. The first thing to be considered is what interests will be benefited. Will it benefit the city of Chicago to put all their freight, passenger and other railroad facilities in one place? I do not think it will for the reason that the majority of the business, both passenger and freight, will have a longer distance to go, both into the city and out of the city, than to the present depots. For the same reason it will not benefit the people outside of Chicago who do business here.

Apparently the only interest that would be facilitated is the exchange business between the eastern. and western roads, the amount of which is comparatively small and which the city of Chicago is but little interested in. According to Mr. Sattley's figures about 72 per cent of the passenger travel is suburban. Of the remaining 28 per cent probably 4-5ths or 22 per cent is local, leaving only 6 per cent which is exchange business between the roads, and of this 6 per cent probably one-fourth or more is transferred in the same depot in which it arrives, so that on a reasonable estimate about 5 per cent of the passenger business would be facilitated, while the remaining 95 per cent would be more or less obstructed by the plan under discussion.

Mr. Sattley—In regard to what Mr. Bremner has said as to the congested condition of passengers on the streets leading to the Terminal Station, I merely mentioned widening the streets to 150 feet; they could be made as wide as 400 feet, if necessary.

In regard to the dockage he speaks of, this is only to provide for what has been changed in the property. These freight-houses can be used just exactly as they are now. This freight station is only located here to take the place of the changed condition.

It is located on space 1,200 feet wide and 1,050 feet long. This is equivalent to 2.18 miles of out-freight (30 feet), 2.18 miles of in-freight (52 feet) and 6½ miles of storage freight. I say 6½ miles, that is only giving three stories for storage. I want to say one more thing about this freight station. The capacity of that freight station is 6½ miles. That means 33 trains of 26 cars each, 40 feet to the car. Now there are three strings opposite each one of those freight houses. Nine trains can pull out of this freight yard and not one train cross the other. Now the capacity of these river slips here are only to take the place of the changed condition. They are not to take the place of anything down here.

The transferring of freight from these roads that come in here is done from a roller lift bridge—a four-track bridge- Please bear in mind that this is only to take the place of the changed condition. I do not propose to congest anything more than what we replace.

Mr. Gookins—What would be done with the Illinois Central and North-Western passenger stations?

Mr. Sattley—Those stations are to be left for their suburban business just the same as they are now. I leave the entire Illinois Central just as it is. I would connect the business center by this tunnel loop and by a viaduct loop in such a way that a person can get to and from the terminal with very little inconvenience.

Mr. Bremner—If you propose leaving the North-Western and Illinois Central stations where they are, I suggest that you also leave the other four.

Mr. Gerber—I would like to ask if Mr. Sattley has made any estimate of what this would cost.

Mr. Sattley—I have roughly gotten at it in this way. I think the rent for the accommodation would pay 3 per cent on $90,000,000. You will have to guess at what it would cost.

E. E. Russell Tratman (*by letter*)—This paper deals in an interesting manner with a difficult and complicated problem, and the author has evidently gone into the matter very thoroughly. Such a station would certainly be a great advantage for through passengers. The difficulty of securing the co-operation and mutual consents of a large number of roads is a formidable one at the outset, even in view of the tendency towards consolidation, but this is a matter rather outside the scope of the paper. Apart from this, and dealing with the question of the solution of the problem of planning a central terminal, there are two fundamental questions to be considered; First, Is it advisable from the operating and financial points of view to concentrate the whole of such an enormous passenger and freight traffic at one terminal. Second, Is it practicable to so concentrate this traffic, and to provide sufficient facilities and accommodation, without having a terminal station so large and extensive as to be difficult for successful operation and to be a source of confusion for passengers. The possibility of congested street traffic by a concentration of the heavy suburban traffic at one point must also be considered. In other words, might it not be better, from an operating and financial standpoint, as well as from a standpoint of convenience, to have the enormous traffic of such a city as Chicago served by two or three terminal stations designed on modern principles for the efficient handling of trains, passengers, baggage, freight, etc.? The city of Boston, for instance, has concentrated the traffic of eight terminals into two large terminal stations. The largest of these has 28 tracks and a double track underground loop for suburban trains. All the existing terminals in Chicago are capable of radical improvement, both in the arrangement of the stations themselves (the waiting rooms, ticket offices, baggage rooms, etc.), and in the track plan and approaches.

A visit to the site of the proposed new terminal will show that it possesses many special advantages. A large proportion of the area is already occupied for railway purposes, and it seems very probable that the confusing series of tracks running in all directions and laid by various independent lines could be rearranged by the engineer so as to utilize all this space to very much greater advantage than at present.

The Chicago Elevated Terminal project of 1891, which was promoted by Gen. Torrence, was to include the elevation of tracks leading to a Union Passenger Station at the southeast corner of State and Twefth streets; the building being 290x350 feet, and the train-shed 1080x290 feet, with seven pairs of tracks, each pair connected at the ends by a transfer table. This station and its elevated approach was to have taken the place of the freight sheds and track of the Atchison, Topeka & Santa Fe Railway along State street, and agreements were made between the terminal company and this railway, but the project never matured. The terminal was to be for all the roads entering the city, including ten trunk lines. For each road there was to be a freight yard and freight station, all these stations being 8 stories high, and provided with 100-ton elevators. Yards outside the city would provide for the transfer of through freight.

The Chicago grade crossing commission of 1892 recommended that all railway tracks, passenger and freight, should be absolutely removed from the territory bounded by State street, Madison street, Canal street and 22nd street. A large part of this territory was, and is, occupied by freight yards and freight sheds, as shown by Mr. Sattley's map; while within it were also three passenger terminals—the Union Station, VanBuren Street Station and Polk Street Station; it now also includes the Grand Central Station. For the lines entering from the south an elevated union station at 22nd street was suggested. This was a very radical proposition and was not favorably received, but certainly the maintenance of extensive freight yards and of large single-story freight sheds within the business part of the city is not a credit to the city or the railways. The land is much too valuable to be occupied in this way, besides which it greatly reduces the value of all adjacent property.

In a paper on "Yards and Terminals," read before the Western

Railway Club in December last, I showed that in many cases it would be economical to abandon large city freight yards, selling the land or utilizing it for more remunerative purposes, and establishing outlying switching yards, with a limited number of tracks running to central freight stations. With city yards, great attention should be paid to the question of utilizing the area to the greatest possible advantage and to its maximum capacity. The tall office buildings afford an example. A property owner increases the earning capacity of his lot by making additional lots, one above the other, in a twelve or twenty story building, without buying additional land. In the same way, in many cases, a small area may be utilized by building tall freight stations, with tracks on at least two levels, the upper floors being used for storage. The cars may be handled on inclines or by elevators. Certainly, the acres of city land in Chicago covered by tracks and single-story freight-houses, and the occasional proposals to purchase additional land for such similar purposes, do not indicate a realization of this problem of the economical use of property. This matter of the concentration of freight traffic is one of the most important features of Mr. Sattley's paper, especially in view of the recent establishment of large shipping yards outside the city by independent companies, which would relieve the city yards of much of the present traffic.

Coming back to the question of the passenger terminal, the proposal to establish a union station at 22nd street was too radical and would have involved extra street car fares for practically every passenger, which would have been a hard burden for many of the suburban passengers. The 12th street location was also too far south, and I think even Mr. Sattley's proposed location would be rather too far south, though the business section of the city is slowly extending below Van Buren street. His proposed suburban station would be at Taylor and 12th streets, which is quite a distance south of the general business district, which should be served by the suburban trains.

Mr. Sattley says that the fact that the Chicago & North-Western and Illinois Central Stations have 28 and 29 per cent of the city and suburban traffic indicates that the present location of these two stations is near enough to the business district to meet the wants of the city and suburban residents. As far as the Wells Street Station of the Chicago & North-Western Railway is concerned, I certainly dissent from this view, and consider the Wells Street Station the most inconvenient in the city for this class of traffic. A few months ago when looking for a country residence I visited places on several of the roads, taking the C. & N.-W. Ry. last of all on account of the inconvenient location of its terminal. It so happened that the most desirable combination of property and train service was found on that road, but the walk to and from the Chicago station is a nuisance, especially considering what wretched streets this city has. This can only be avoided by paying an extra fare for street or elevated car. The street cars and omnibuses indicate that this station is inconveniently located. The 12th Street Station of the Illinois Central R. R. is equally inconveniently situated, but the bulk of the city and suburban traffic of that road centers at the Van Buren Street Station, which is much more convenient.

The idea of separating the suburban and main line traffic is decidedly good, but it seems as though the suburban station should be north of the other two portions. In the Boston southern terminal the separation is vertical, the suburban tracks being underneath the main station. At first glance one is rather surprised that Mr. Sattley has not introduced the loop system, as has been done at Boston, but a little consideration appears to show that this would be rather difficult to introduce into a station used by so many roads having a number of suburban services. In his system, as I understand it, the empty trains run from outside yards and through the station to storage tracks beyond the station, where a number of trains may be held ready to pull out in the same direction, avoiding all reverse movements.

In regard to the separation of trains, it would seem better to separate the incoming rather than the outgoing trains. Persons going to the double station proposed will very often get to the wrong part. It is true that the two stations are on opposite sides of the same street, but still the arrangement would probably be a source of confusion, especially for strangers. The trains would make no such mistakes, but would deposit their passengers at the suburban and main line stations respectively. By separating the incoming trains, the suburban and main line passengers would be automatically separated, and all outgoing passengers would concentrate at one point.

In regard to the track plan, the avoidance of crossings and the maintenance of non-interfering tracks for the several roads is a most important feature in regard to the efficient handling of the traffic. It seems doubtful, however, whether the proposed arrangement would give sufficient capacity, especially during the rush hours of suburban traffic, even with trains feeding in from behind, as described. To take an instance: It would seem that the Chicago & North-Western would have four tracks, with only one outgoing track for suburban trains. The present station of this road has ten tracks for its incoming and outgoing main line and suburban trains. One of these is for the baggage cars of outgoing trains. The other nine tracks are used interchangeably for incoming and outgoing trains as required. It is true that most of the tracks are stub tracks, and one train cannot enter until another has pulled clear out; but three of the tracks run through, so that an incoming train when empty can pull out of the way of another train, or an empty outgoing train can pull in as a loaded train pulls out. The traffic at this station (C. & N.-W. Ry.) could be greatly facilitated by a four track bridge over the river, so that trains of the Milwaukee and Galena divisions could be kept separate as far as the junction on the west side of the river. This passenger terminal can also be enlarged by placing new tracks in the space between the present tracks and the river.

Another feature which seems liable to reduce the capacity of the proposed union central station, and to introduce serious operating difficulties, is the lack of flexibility in the apportionment of tracks. Each road is allotted a certain number, and it would be difficult to afford additional accommodation for any one road which might have an exceptional traffic due to excursions, etc., for the reason that tickets are to be marked with the number of the tracks for transfer. If three or four roads had similar traffic, there would be liability of confusion and delay. Excursion traffic, it may be noted, is different from suburban traffic, in that the passengers are not so quickly handled, and there may be large quantities of baggage to be handled. Any temporary use of tracks of one road by trains of another would seem to be impossible, owing to the system of ticket numbering and punching described in the paper.

While discussing the matter in regard to traffic, it may be noted that while the table of trains at the various stations shows a sufficiently heavy traffic in number of trains, it does not show the additional difficulties due to the concentration of these trains; that is to say, the train arrivals and departures are not evenly distributed throughout the day. The suburban traffic on all the roads is concentrated within a few hours, and main line trains of different roads (but having the same objective point) generally leave about the same hour, so that the roads would use their tracks simultaneously. Furthermore, four roads use one pair of the tracks, but it is probable that two or more of these would require to start trains at about the same time, and in the event of any one of these roads having an extra traffic considerable trouble would be experienced. It seems doubtful whether it would be wise to have tickets stamped, as suggested, since this would prevent any flexibility of accommodation to provide extra facilities temporarily for any one road.

The movable sidewalk plan is theoretically alluring, but considering the number of elderly and invalid persons, as well as country folks and others unused to the rapid ways of city life, it might seem that such a device would be a source of endless confusion.

Mr. Sattley proposes to provide good facilities for traffic between the station and the business part of the city by wide streets, viaducts, elevated walks, an elevated railway loop and the suggested underground loop. A commendable feature of this part of the scheme is the provision for a broad open space at the station, to facilitate the handling of crowds. All the existing stations are entirely lacking in such facilities and are awkardly located on narrow streets, so that the handling of crowds or troops is a difficult matter, and visiting celebrities have to be treated in a more or less undignified manner. As to æsthetic surroundings, such as are found at many important European terminals, Chicago has nothing to offer but wretched dirty streets and miserable buildings crowding the stations. Plans are reported as being prepared for new terminal stations at Wells street and Van Buren street, and it is to be hoped that advantage will be taken of the opportunity to throw the stations back, and at least have a court-yard for vehicles, instead of putting the station right up to the sidewalk line and compelling the station traffic to continually interfere with the street traffic.

The general scheme so carefully worked out by Mr. Sattley is attractive and offers many points for careful thought. It would require comparatively little purchase of property and would make much other property available for sale for purposes more advantageous to the city. There are many difficulties in the way, notably the difficulty of getting the necessary co-operation of the various railway companies and of the city, the latter being necessary in providing suitable approaches, to prevent congestion of traffic between the station and the business section of the city. In view of the large proportion of the area required which is already available, and in view of the value of the sites of the present stations which would ultimately be available for sale, the cost would probably not be so great as in cases where large areas of valuable property have had to be acquired, as in the cases of the Boston southern terminal and the St. Louis terminal. The value of the lands acquired for the Boston terminal was about $9,000,000. The great advantages of such a central union station would be as follows: (1) The reclamation of valuable property now occupied by tracks and sheds and not used to good advantage. (2) Improved facilities for through passengers. (3) The establishment of a station of modern design in keeping with the commercial and æsthetic requirements of the city.

As to the means of carrying out such a project it may be noted that for the great southern terminal at Boston, a terminal company was formed in 1896, consisting of the five railway companies interested (since consolidated into two companies); each took $100,000 of stock, all other funds being raised by terminal bonds. It is managed by a board of trustees. In this connection I would quote the following remarks from the paper on "The Southern Terminal Station at Boston," read before the American Society of Civil Engineers by Mr. George B. Francis in 1900:

> "While it is not always the duty of the engineer to discuss the wisdom or necessity of certain lines of policy, and while discussion is more or less unprofitable, it may, nevertheless, in this instance prove valuable to answer in advance the questions sure to be raised as to whether such a large terminal, with its accompanying expenditures, is a proper investment for a railway company to make.
>
> "When railway stations have been utterly outgrown, as was the case in Boston, and the traffic cannot be properly handled, there is no alternative for the railway management but reconstruction. The question whether each of the existing stations shall be enlarged, perhaps under great difficulties, or whether a combination shall be effected, as in Boston, for the mutual convenience of the transportation companies and the public, is usually well weighed and decided by those most competent to decide. Having decided to build a new station, no management can be criticised for making it an up-to-date and even ahead-of-date structure.
>
> "Of the great expenditure necessary for the new terminal station in question, probably two-thirds of its entire cost for land and buildings reverts directly or indirectly to the railways interested, in lands released at old stations for other purposes or for entire disposal. With bonds selling at a premium on a 4½ per cent basis, much more can be accomplished, with the same interest charge, than was possible a few years ago, with interest at 6 per cent.
>
> "As far as can now be determined, the cost of operating the new and much more commodious station will be about the same as the sum of operating the old stations.
>
> "A railway station is a minor appurtenance to the road itself, and it is impossible to always incur expense for renewals on the basis of an investment upon which a new direct return will be forthcoming.
>
> "It may be compared roughly to a new storehouse for a cotton mill. It is a necessary convenience for the handling of the business, but the mill (or the railway) is the real earning factor.
>
> "The question has been asked: 'How much did the city of Boston contribute toward the construction of the station?' In reply, it may be said that not one dollar was contributed, directly or indirectly, by the city for land or structures upon the terminal location. The city, through its own departments, was authorized by the legislature to expend a sum of money for streets and bridge construction, outside of the terminal property, not to exceed $2,000,000."

As an example of the extensive and varied equipment and appliances of a large passenger terminal, I give the following details of the Boston southern terminal, as kindly furnished me by the manager of the Boston Terminal Company:

Station dedicated, December 30, 1898; operated, January 1, 1899. Total area of land, about 35 acres; covered by buildings, about 13 acres.

MAIN STATION.—Length, maximum, 850 feet; width, maximum, 725 feet. Length, average, 765 feet; width, average, 622 feet. Area, 506,430 square feet. Area of awnings outside buildings, 46,000 square feet. Height from sidewalk to top of eagle, 135 feet. Height from sidewalk to top of flagpole, 200 feet.

EXPRESS BUILDINGS.—Length, 712 feet; width, 50 feet.

POWER BUILDINGS.—Length, 569 feet; width, 40 feet.

Total length of buildings on street front, 3,300.

TRAIN-SHED.—Length, 602 feet. Width, middle span, 228 feet.

Height over all, 112 feet. Width, two side spans each, 171 feet. Total width, 570 feet. Trusses, catilever, and 60 feet center to center.

Midway.—Area, 60,000 square feet; of connecting roofs, 17,500 square feet.

Waiting Room.—Length, 225 feet; width, 65 feet; height, 28½ feet.

Tracks.—Total length, about 15 miles; length under roof, 4 miles. Total number entering stations, 32; 28 on main floor and 4 in the shape of two loop tracks in subway. Number through throat in yard, 8 for main floor; 4 for subway. Total weight of rail, 2,500 tons at 100 lbs. per yard. Switches, double, slip, 34; single, power, 51; single, hand, 52; switches, single, total, 103. Frogs, rigid, 173; movable, 68; frogs, total, 241.

Interlocking.—Semaphore signals, high type, 109; dwarf, 28; total signals, 137. Levers in tower No. 1, 143; No. 2, 11; No. 3, 11. Signal lamps, electric, 182; signal bridges, 9.

Total number of trains using station, week days, 750 to 780; Sundays, 220.

Passengers carried by these trains, per annum, about 25,000,000.

Number of 65-foot passenger cars that can be set against platforms on main floor, 344; of these, 252 will be under one roof.

Number of 40-foot passenger cars that can be set against platforms in subway, 60.

The seating capacity of the above cars is 28,104 people.

Capacity of express yard, against platforms, 26 express cars, 12 mail cars.

Total capacity of mail and express yard, 116 cars.

Capacity of other yard tracks, 93 cars.

Making a grand total of 613 cars.

Cars to and from the station, daily, about 3,000.

Mail and express cars to and from express buildings, daily, 150 to 350.

Numbers of movements through throat in yard for main floor, 3,000.

The clock dial in tower is 12 feet in diameter; and the granite eagle is about 8 feet high, 8 feet wide, and weighs 8 tons.

Number of pieces of baggage handled, annually, about 1,500,000.

Number of parcels handled in parcel room, annually, about 350,000.

Number of tons of mail handled, daily, about 150.

Number of persons employed at station, including office forces of the different railway and express companies, trainmen, and railway mail service employes, 2,500.

Capacity of ice plant, daily, 25 tons.

Capacity of gas plant, daily, 120,000 cubic feet.

235 arc lights.
6,000 incandescent lights.
1,200 incandescent lights in main waiting room.
20 water meters.
29 storage vaults.
106 fire supply outlets.
215 office rooms.
1,000 window shades.
209,000 lbs. sash weights.
150 Pintsch gas connections.
56 steam heat connections.
48 air-brake test connections.
11 steam boilers.
4 electric generators 225 KW.
1 motor generator.
50 electric motors.
10 compressors.
17 steam engines.
19 heating and ventilating fans.
1 traveling crane.
13 steam pumps.
2 draft fans.
25 electric elevators.
207 water closets.
177 urinals.
6 shower baths (for trainmen).
143 set bowls.
26 sinks.
50 toilet rooms.
36 ticket windows (including subway.
90 baggage room doors.
71 express building doors.
77 clocks, electric, self-winding.
3 fire alarm boxes and 21 auxiliary stations.
1 watchman's time detector and 33 registering stations.
31 fire risers with 106 outlets.
50 miles piping.
⅝ mile 8-inch circulating pipe

APPROXIMATE AMOUNT OF MATERIAL USED TO COMPLETE THE WORK

43,816 spruce piles.
15,100,000 common brick.
487,000 medium brick.
846,000 enameled brick.
8,000 barrels coal tar pitch.
850,000 lbs. tarred paper.
16,000 lbs. solder.
150,000 square feet wire glass.
40,000 lbs. putty to set same.
200 acres painting (reduced to a single coat).
30,000,000 lbs. or 15,000 tons steel, equal to about 1,200 carloads.
200,000 cubic feet cut stone for building, or 500 carloads.
74,000 cubic yards concrete.
32,000 cubic yds. stone masonry.
75,000 barrels Portland cement.
20,000 barrels Rosendale cement.
6,500 barrels prepared asphalt.
5,000,000 feet, B. M., yellow pine.
10 acres gravel roofing.
56,000 square yds. waterproofing.
425,000 lbs. sheet copper for roof trimmings.

J. C. Stuart (B. & O. R. R.) by letter—I desire to take this opportunity of congratulating Mr. Sattley on his efforts in developing this subject. It is a most difficult problem, and the solution of it in any way, no matter how difficult, would deserve the commendation of those interested in such matters. There is no doubt but that Mr. Sattley's theory on the subject is an ideal one, and if it were possible to secure sufficient ground in any convenient location in Chicago, and properly care for all in-bound and out-bound passenger trains, and make it convenient for the public to use such a Union Station, the arrangement would certainly be very desirable.

The first question, however, that presents itself to my mind, upon reading the paper, is whether it would be possible to accomplish the suggestion under any plan, and, from my knowledge of conditions, business, financial situation etc., I have no doubt but that it would be impossible to develop an arrangement of that kind, even if most of the objections to it were removed.

There is a most excellent Union Station in St. Louis, and people who are familiar with it and appreciate its value are prone to ask the question, "Why could an arrangement of that kind not be installed in Chicago?" The reasons are that Chicago is a much larger city, consequently has a much greater traffic and has a great many more trains, so that, at the present time in the United States there is no precedent for establishing a Union Station in a city as large as Chicago.

If, however, such a scheme could be developed, we would prefer this suggestion for a Union Station:

Secure through the State Legislature and the city authorities the right to fill in and make sufficient ground in Lake Michigan, on the lake front, at some convenient location for the construction of a joint station. Have the railroad companies pay to the City of Chicago a sufficient ground rental to make the franchise a desirable one. Have the station of right angular or L shape; divert all eastern and southern trains to the lake side at or near South Chicago; permit the Illinois Central railroad right of way to be extended so as to care for all the roads just mentioned, and bring them into one of the lines of the right angle mentioned; then have all the west and northwest lines come in at some point parallel to the main stem of the Chicago river and reach the other line of the right angle in the same locality.

While this would give you a Union Station, it would practically take care of the business under two sheds; west and northwest one, and east and south the other; for simply handling passenger traffic, letting the freight stations, etc., remain as they now are. Then have the loop line connect with this station so as to make it possible to get to any part of the city over the elevated railroad.

This scheme is, of course, subject to the same criticism as Mr. Sattley's plan, for the reason that we do not believe it would be possible to carry it out.

Inasmuch as the two propositions (Mr. Sattley's and the one I have just suggested) are impracticable, the next best arrangement to take care of the passenger traffic in Chicago is to have excellent and direct connection with the elevated loop, at the several present railroad depots.

CXXX.

MODERN PRACTICE IN BRIDGE SHOP WORK.

W. H. Pratt, M. W. S. E.

Read Sept. 4, 1901.

The modern bridge or structural shop, like everything else known to man, is a product of a condition of things. The principal factors in the condition of things responsible for bringing about and developing the present bridge shop have been the increasing demand for its products at the current market prices, the most suitable tools and appliances to be had from different sources, improvements in these tools and appliances, and a working force of men organized on a basis commensurate with the importance of the undertaking.

About thirty years ago the cost of iron was reduced to a point admitting its quite extensive use for members of frame structures where great strength and durability were required. The demand for this class of work then became sufficient to bring forth and maintain special shops for its production. These shops were equipped with shears, punches, drills, riveters, milling machines and boring-machines already in use in boiler shops and machine shops. The corresponding tools of to-day differ from those in the earlier shops more in quality than in kind. They are now generally built stronger and are better adapted to their special uses, but every essential machine and tool had been used by the boiler-maker, ship-builder or in the machine shop.

The transmission of power by electricity and the more extensive use of compressed air have recently become important factors in reducing the cost and increasing the output. In the earlier shops little attention was given to the arrangement of tools and processes, or to appliances for handling. As the volume of business increased, machines were improved and perfected, materially reducing the cost of work done by them. It was then apparent that the handling of materials was relatively too slow and expensive. Carrying hoists, operated by air or electricity, have now become indispensable.

Many of the first bridge shops were started in old buildings which had been used for other purposes. These old buildings and those built specially for the purpose were added to as more space was required. As the volume of business increased and the weight of pieces became heavier, the buildings needed to be reconstructed to meet the new conditions, and some of them have been replaced with more roomy, stronger and better lighted structures, designed to support carrying hoists and provide for a more convenient arrangement of processes.

Up to the present time local conditions have to a certain extent governed the shape of buildings and the arrangement of processes, and there are probably few if any bridge shops which conform to a plan which would be considered ideal by the men responsible for their arrangement. Although improved mechanical arrangements have done much to improve the grade of workmanship and lessen the cost of structural iron work, superior skill and organization have accomplished still more in these directions, and I believe that if a modern shop force could be put to work in one of the earlier shops of thirty years ago, a greater part of the improvement in workmanship and reduction in cost which has taken place would be obtained.

In future, greater improvements must be looked for in the plant than in the organization. Skill may be developed independently of output, but most of our appliances materially reducing the cost of production, force their way to perfection and adoption after the volume of product demanded has been materially increased.

The quantity of structural shapes rolled in this country has increased more than three-fold during the last ten years, and no demonstration is required to show that any real improvement in either method or appliances is worth more than three times as much today as it was ten years ago. With this inducement and the prospect of a still further large increase in volume, we may look for more marked improvement in the appliances of the future than has been made in the bridge shops of the past. Better workmanship will be demanded in the construction and maintenance of tools and appliances. More attention will be given to the arrangement of buildings and efficiency of processes. The highest skill, even with an increased wage, will be more apparent as the best economy.

DISCUSSION.

Mr. Finley—I think one of the factors in the development of shop practices has been the improvement in draughting. My earlier training was with the Edge Moor Iron Company, and I am satisfied now, from looking over the field, that it was fifteen or twenty years ahead of its time. I think that during the time it was producing it never got the credit for the methods and operations they were using. They have largely been adopted by all the bridge companies in the United States to-day.

Mr. Schaub—I am sorry that you called on me, because I feel that I can add very little to what has been said. I was a little disappointed in not hearing one thing brought out by the author, and that is the question of reaming. It is an old question, to be sure, but I would like to know how the shop men feel about it.

I have been making some experiments recently on rivets driven in reamed holes, and find them so much better than the ordinary rivets which were in unreamed holes, that we would be justified in using a fewer number of them in designing work with riveted connections. Moreover, there would be less holes to punch, less holes to ream and less rivets to drive—a very important consideration in the field work. I would like to hear some expression from Mr. Horton, as I know he is violently opposed to reaming. There is a shop here which is well equipped for reaming, and that is the Lassig Branch of the American Bridge Company. Mr. Ziesing can tell us something about that.

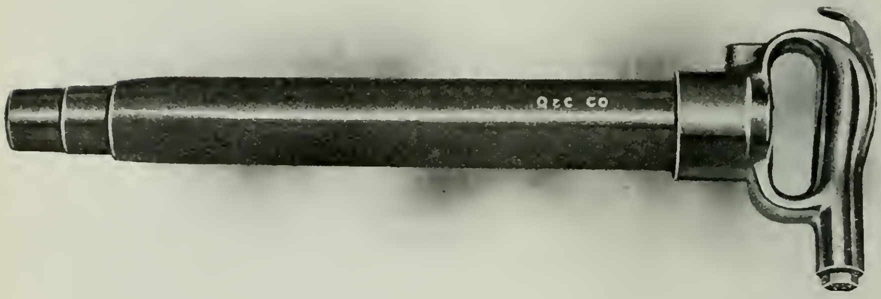
Mr. Ziesing—I agree with Mr. Pratt in thinking that the bridge shops have not advanced as rapidly as they should have in the matter of tools and appliances, nor have they settled down to the best arrangement of shops. If you go through the different shops in the country you will find that there are as many different opinions on the proper arrangement of shops as there are owners of shops. The trouble is that all the bridge shops in the country have grown up from small shops to their present capacity, and as there was a certain rivalry between all bridge manufacturers they have not to any extent exchanged opinions, and each has worked out his own problems on lines laid down by himself, and the result is that there are hardly two shops having systems that are alike. I think that there is room for improvement there, and I can say there is not a shop in the United States that can be pointed to as a model bridge shop. The time is coming when this will be corrected, but at the present time that is the case.

In regard to reaming, I will say that I believe in reaming—always have; but as to whether the bridge that is reamed will really last longer than the bridge that is simply punched is still a question to be proven. It costs more to ream, notwithstanding the fact that fewer holes are needed. Whether you punch twelve or fifteen holes for a connection cuts very little figure; it costs almost the same. A large portion of the cost is in the general expense and the handling of the material through the shop.

Mr. Modjeski—I came here to learn some things and therefore I would like to ask a few questions.

There is one little tool which seems to be quite universally used now that I would like to ask about, and that is the air hammer riveter. I understand some objections were made in the beginning of its use that it did not fill the rivet hole properly; since then they have been made heavier, and I understand that objection has been remedied.

I would also like to know if anybody has made any experiments by cutting through a rivet hole to see what effect the rotary motion generally imparted to that riveter has on the shape of the metal inside. It seems to me that the moving about on the rivet as it forms the head is injurious. I have not made any experiments and would like to know if anyone else has.



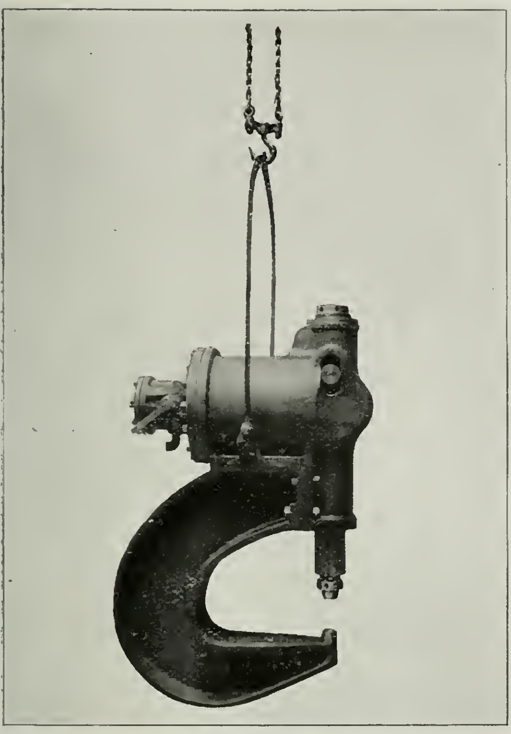
Hand Air Riveting Machine.

Mr. Pratt—I have made some experiments along the lines that Mr. Modjeski speaks of, and find that the pneumatic hammer we use fills the holes even to the corners much more thoroughly than the hammer driver. The rotary movement on the head of the rivet is given for the purpose of cleaning up the head after the upset in the rivet is made. If more stock is used than is actually required for the head, it can be rounded up with a rotary movement if it is properly done. It is better to use a little more stock than is actually required, and it can be properly finished in this way. I will say that samples of ¾-inch rivets with a grip of 1 to 1½ inches show very slight cavities and sometimes none, even in the corners. There is usually some little corner not quite filled that could be completely filled with a powerful pressure riveter. When the rivets are carefully driven, the work is unquestionably superior to hand work.

Mr. Finley—Do you still consider it equal to hydraulic driven rivets?

Mr. Pratt—No; any pressure riveter with proper power will do very much better work than these hammers.

Mr. Ziesing—Do you think there is any riveter that will fill a hole



Duplex Cylinder Pneumatic Pressure Riveter, with Toggle Mechanism.

through a thickness of more than 1½ to 2 in. of plates? Will the rivet fill the hole? Is there any riveter that will do it?

Mr. Pratt—Yes, I think seventy tons on ¾-inch rivets, well driven, will do that unless the offsets are extremely bad. If it is a reamed hole it will do it thoroughly.

Mr. Ziesing—In the case of a punched hole, will it not form a head, and kink or bend the material under the head instead of upsetting it? The excess of material in your rivet will not upset inside of the hole, but will form a "fin" under the head of the rivet.

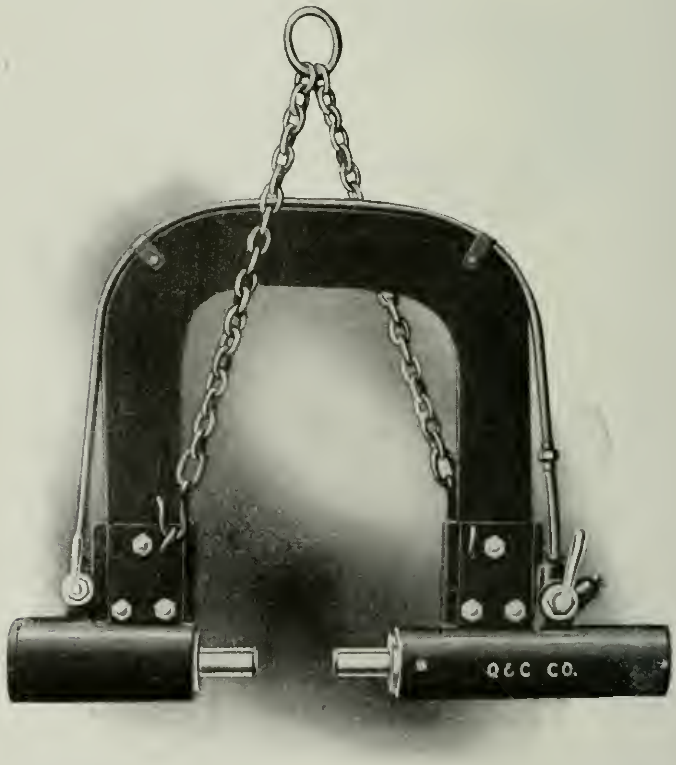
Mr. Pratt—It is pretty hard to say just what length of grip will cause that. In good work holes have been filled very satisfactorily, very thoroughly. I think that it can be done generally with a powerful machine, 70 to 80 tons pressure, for both ¾ and ⅞-inch rivets. Of course, samples are usually more carefully done than in ordinary work, but there ought not to be very much difference.

Mr. Ziesing—We made some experiments some years ago for the C., B. & Q. in driving rivets by hand, by steam and by air, through certain thicknesses of metal. The metal that they were driven through consisted of iron pin metal with drilled holes so that the holes were smooth, and after the rivets had been driven the specimen was put on to a lathe and turned. Sections of the pins, say about ½ inch in width, were cut down to the shank of the rivet, thus cutting the pin into so many rings on the rivet. We made quite a number of tests of that kind, and found that each one of these rings, after they had been cut so that they were independent of each other, was loose on the rivet, with the exception of the two that were under the two heads. Each one of these rings would turn on the rivet with the exception of the two rings immediately under the heads, which showed that the rivet, instead of upsetting and filling the hole, buckled in the hole, one ring bearing on one side and the next on the other side. When we cut them apart we found no rivet really filled the hole sufficiently to hold the rings from turning.

Mr. Finley—I saw these same experiments that Mr. Ziesing refers to, but I understand they were also driven by hydraulic power.

Mr. Ziesing—Only steam, air and by hand. They were very careful to head the rivet as well as the men knew how, and drove them as solid as they knew how.

Mr. Finley—I understand the Locomotive Boiler Works have abandoned the use of steam and air riveters and have adopted hy-



Pneumatic Percussive Riveting Machine.

draulic machines, as they could not get the results by any other process.

Mr. Horton—In regard to the question of vibratory pneumatic riveters. We have had a little experience in the way of a test, using the largest size machine made by the Q. & C. people. A yoke with a 3-inch air jack hold-up was used. The machine was worked with 80 pounds pressure; six plates each ⅜-inch thick were riveted with rivets ⅞-inch, six rivets in a row, four rows; and, much to my surprise, none of the rivets went loose. We planed out two rows and found them filled as well as rivets usually do.

The objection principally to their use is that it is not an economical instrument to use in shops. With reference to air, steam or hydraulic power, I think it is a question more of detail than anything else. It is the exception to find a riveter that can put 75 tons pressure on a rivet. Undoubtedly 75 tons pressure is desirable for the best results.

Certain hydraulic riveters are in use which put a great initial pressure on the parts that are to be riveted before the driving of the rivet, and unquestionably this is an advantage to the work; but such machines are not portable and their use is therefore limited. Portable hydraulic riveters do not have this desirable feature, but are superior to the pneumatic riveter in the fact that they do not require such close adjustment for varying thicknesses of plates and amount of stock in the rivet. I look for an early modification of the pneumatic riveter to avoid the objection referred to, and make it fully equal in adaptability to the hydraulic machines. I think I am justified in the belief in expecting that the riveting in the bridge shops will continue to be done by portable rather than stationary machines.

Steam machines have not been mentioned here because of the objection to them, owing to the condensation in the pipes and the heat from the machines.

Mr. Schaub made a statement to the effect that I was opposed to reaming for riveting. I most emphatically object to reaming the holes, on the theory that I can do it more cheaply than merely to punch them.

Mr. Allen—I was formerly connected with the same bridge company as the chairman, Mr. Finley. They used to use direct-acting hydraulic power for driving all rivets. I know that the almost universal practice in the west is to use air toggle machines; but it has always seemed to me that a direct-acting machine is far superior to a toggle machine, not because a toggle machine cannot exert the required pressure, but because it requires that the grip be nicely adjusted every time the thickness of metal is changed, and this adjustment is not always made correctly. If the grip is not exactly right, the toggle machines do not give anywhere near the pressure for which they are capable. With a direct-acting hydraulic riveter the power is applied more slowly and uniformly, the upsetting is more complete, and you are sure to get the entire capacity of the riveter every time a rivet is driven.

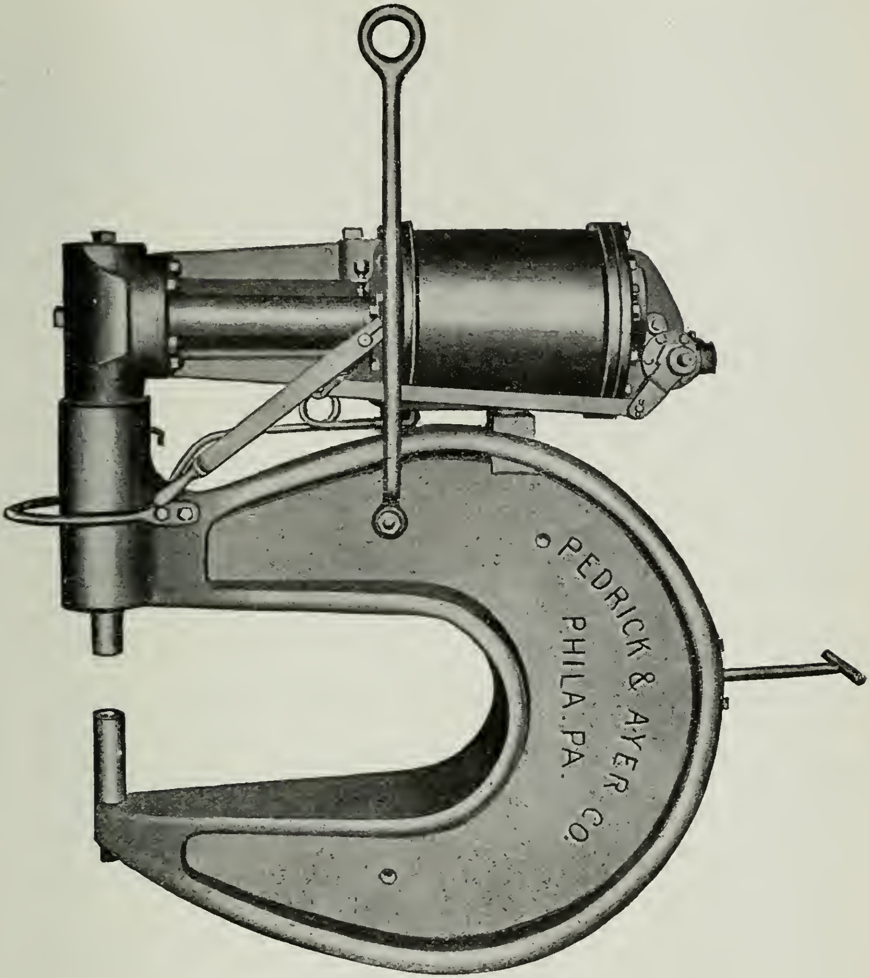
We have at the present time in our shop in Milwaukee a pneumatic-hydraulic riveter which is direct-acting, thus combining the convenience of an air machine with the advantages of direct-acting hydraulic power.

In regard to reaming. At Edge Moor we always used to run a reamer through all the holes to true them up, and the difference between taking out 3-16-inch metal and simply truing up the hole did not show up very seriously in the cost of the work. In explanation of the fact that we had to ream all the holes, I might state that we used a multiple punch, and I believe that the universal experience with such a machine is that it is very hard to match the holes in the web when the holes of the flanges are punched in this way; the stretch is hard to allow for exactly, since you cannot vary the spacing by less than ¼ inch.

Mr. Schaub—The point brought out by Mr. Allen, in regard to the difficulties in operating a pneumatic riveter, is a good one. However, I understand that there is an air riveter on the market now, made by Pedrick & Ayer, of Philadelphia, which is operated by the use of air and oil combined, which overcomes all of the difficulties found in the ordinary pneumatic riveters.

Mr. Finley—I think Mr. Pratt can tell us something about these machines.

Mr. Pratt—Yes, I have used those machines for two years now and find them very efficient and satisfactory. They are new and some of the details are susceptible of improvement. For instance, the packing; in some cases the walls between the chambers are extremely thin, but it is hard to keep the packing in with the heavy pressures. All these defects are susceptible of correction, of course, and when the machine is fully developed it will undoubtedly come into more general use. The machine is very cleverly designed in that the air will operate the hydraulic piston independent of the hydraulic power, and will move the tool back, bringing it up against the rivet. The hydraulic power is only used to upset and head the rivet after the cup has been brought in contact with it. The action is controlled by a single lever; the action is quick and corresponds to that of a hydraulic riveter. It can be used stationary or portable. It is as light as the toggle-joint riveter of the same power and capacity. The great objection to the toggle-joint riveter is that the tool has no movement at the maximum power,



Hydro-Pneumatic Pressure Riveting Machine.

and it requires an extremely skillful mechanic to do good work with it.

Mr. Ziesimg—I would like to ask whether you have found any marked difference in the work of the different kinds of machines, or whether it has not been more the shop manipulation of the machine?

Mr. Bainbridge—I have found a very decided difference. A direct-driven rivet is unquestionably the best. In driving direct they do not usually hit the rivet again.

Mr. Ziesing—What is the object in hitting again?

Mr. Bainbridge—It is done for the purpose of fooling the inspector.

Mr. Ziesing—What is the objection to hitting the rivet after a second blow?

Mr. Bainbridge—It is just to conceal the fact that the rivet was not driven home in the first place. It cannot possibly do any good to strike it again. It simply calks the rivet head around the edges.

Mr. Finley—Do you not think the rivet that is driven from one full stroke direct is better than a rivet that is struck three or four times, as in a toggle riveter?

Mr. Ziesing—I have always thought one stroke was better, but have failed to find any facts to sustain me in that belief.

Mr. Finley—I agree with Mr. Allen in his objection to the toggle-joint riveter, from the very fact that it cannot exert its pressure at the proper time.

Mr. Allen—In making a comparison between direct-acting steam and hydraulic riveters, it has always seemed to me that we should consider the fact that steam is expanding, almost explosive gas, and that water is practically non-compressible. In the steam riveter you get more of a blow, while in the hydraulic machine you get a steady pressure and uniform motion throughout the entire stroke. The pressure is what you want, not the blow. That is the difference between the steam and the hydraulic riveter; both are direct-acting and both are good in that respect, but I do not think the steam is the equal of the hydraulic.

Mr. Ziesing—I do not think the steam riveter acts fast enough to exert a blow.

Mr. Pratt—I have used steam riveters and I do not think the action is any quicker than hydraulic, and the samples which have been driven with steam riveters compare favorably with the hydraulic driven. I think the steam riveter does just as good work. A powerful machine will upset a rivet and fill a hole which a light machine cannot do.

Mr. Finley—As I remarked before, I have understood that the Locomotive Works have discarded the use of steam and air riveters, and are using the hydraulic, for the reason that they could not get the required results from the other kinds. Of course, it is quite possible we do not need the same class of work in bridge work that we do in boiler work; but it is very evident that in their experience they found the hydraulic riveter superior to steam or air for their work.

Mr. Allen—Of course, the possible steam pressures are relatively so low, and the piston consequently so large, that a steam riveter is practically limited to the "fixed" form.

Mr. Modjeski—I want to go back to the question of re-hitting the rivets; in other words, of hitting the rivet once and then giving a second blow when it has cooled off. It seems to me the second blow, when the rivet is still hot, does not do any harm; but to go over the rivets again after they have cooled off does not do any good, and those rivets that were loose are simply tightened up by bringing the heads closer together, but do not fill the hole, and the inspector certainly cannot detect them after they have been treated in this manner.

Mr. Schaub—In regard to using hydraulic riveters in preference to air, I am very much of the opinion that the hydraulic riveter is too slow, and that it is one of the reasons why it is not used in bridge shops. You cannot get the quick action with the hydraulic riveter that you can get with the air riveter. There is no doubt that the hydraulic machine will drive the best rivet, and the new hydro-pneumatic riveter now on the market has all of the merits of both hydraulic and air riveters combined. If the locomotive shops are using hydraulic riveters they are not up to date. I understand that the Heine Safety Boiler Works are using the hydro-pneumatic riveter in both of their shops.

Mr. Bley—As I understand it, there are two classes of air riveters; one simply sends them home and the rivet has to be backed up by some outside prop, while there is another form of air riveter, made about the same shape as a hydraulic riveter, in which a part of the riveting device passes around to the back and holds it in place. Which form has been used by people using the air riveters?

Mr. Ziesing—It is a horseshoe shape. In some cases they have the hammer riveter, where a man holds the dolly-bar and another man holds his tool and drives; there are others again where it is in one piece, the same as those driven by pressure only.

Mr. Finley—I would like to ask Mr. Allen if the majority of shops are not using the multiple punch.

Mr. Allen—I do not know as to the majority, but a number of the eastern shops, at least, are using it.

Mr. Ziesing—I think the multiple punch is used in almost all shops in some form or other with some modification. Not exactly the cumbersome machine that it was twenty years ago.

Mr. Finley—I would like to find out just when reaming started in; whether with the use of steel in bridge work or at a more recent date. I think that Gen. Sooy Smith said the Glasgow bridge was the first steel bridge in the United States. Was that reamed or punched?

Mr. Horton—We must not overlook the bridge at St. Louis. It is a steel bridge—a crucible steel bridge.

Mr. Strobel—The first steel bridge with which I had any connection was the Plattsmouth bridge over the Missouri River, Mr. Geo. S. Morison, chief engineer. It was built soon after the Glasgow bridge, and the same Hays steel was put into it that was used for the Glasgow bridge. The tests showed great variations in the physical properties, and there were many rejections at the mills. It would not be fair, however, to attribute these variations to the Hays matte put into the steel, but rather to the general shortcomings of steel manufacture in those days. On the other hand, the experience gained with Hays steel in connection with the Plattsmouth bridge did not induce a further use of it. The rivet holes were punched and reamed for the Plattsmouth bridge, and the steel used for the compression members in these early steel bridges was high carbon steel.

Mr. Allen—Has anyone had an opportunity to judge the comparative merits of an ordinary reamer and a twist drill, both as to cost and to the quality of work? A number of the railroad companies require that reaming shall be done with a twist drill. Our experience has been that we get better results by reaming with a fluted reamer, which scrapes the metal away from the hole instead of cutting through. It does not leave the burr that the twist drill does, and it will follow through a badly matched hole, taking metal from each plate, instead of cutting through in a direct line, and possibly leaving out some edges entirely.

I would like to know the reason for the requirements which some of the railroad companies have made.

Mr. Finley—Personally, I am rather inclined to think that the desire of the manufacturer to use the reamer instead of the drill is because he can do so much more work in the same space of time. My own opinion is that the twist drill is superior in its results to the reamer.

Mr. Horton—I would say that the reason for using the twist drill is that it is more economical to use than a tapered reamer. The expense of the reamers themselves is essentially prohibitive of their use, due to first cost and short life; that is, if you are taking out ¼-inch metal, as is now generally required.

Mr. Finley—You are not with the reamer.

Mr. Horton—You may take the metal out readily.

Mr. Finley—When I stated that the manufacturers preferred to use a reamer instead of a twist drill because it was cheaper, I referred only to those cases where they did not take out ¼-inch metal, but only cleaned up the holes.

Mr. Ziesing—Mr. Horton is right in regard to the twist drill, as it is far the cheaper.

Mr. Finley—Is it more efficient?

Mr. Horton—There can be no question about the efficiency. If a hole is punched 11-16 inch and reamed 15-16 inch, it is quite immaterial whether it is a reamer or twist drill, as far as results are obtained; that is, a 15-16-inch reamed hole.

Mr. Bley—Mr. Horton says "tapered reamer."

Mr. Horton—Tapered on the entering end. If we have a 11-16-inch hole punched, to be reamed to a 15-16-inch, the reamer, from the nature of the case, must be no more than ½ inch at the point, and it must have a taper of some distance—probably 3 inch—before reaching the full and necessary size of 15-16 inch.

Mr. Bley—How are the twist drills held, by a tapered socket or set screw?

Mr. Horton—A Morse tapered socket.

Mr. Bley—Does not the taper socket lose its hold, as the drill gets through the plate, and allow the drill to drop?

Mr. Horton—The gentleman has touched on a tender subject, and if he has any suggestions to make how to hold a twist drill by any other method than by a tapered socket, we want to hear it right now.

Mr. Bley—I am looking for a better method myself.

* * *

CXXXI.

SOME OLD EXAMPLES OF BASCULE BRIDGES.

By Mr. K. Hellenthal, M. W. S. E.

Read February 20th, 1901.

Ever since the first really successful bascule bridges were built over the Chicago river, at Van Buren street and the one carrying the tracks of the Metropolitan Elevated Railroad close to it, rumors were frequently heard that this type of bridge was not new at all, and that some had been built in Europe a good many years ago. One party stated positively that such a bridge was in successful operation in the city of Stockholm, Sweden. Thereupon I sent a complete set of plans of the Metropolitan bridge to the Secretary of the Swedish Society of Engineers, asking him to kindly reply whether such was really the case, giving as my reason the desire to place the credit for the original invention where it belonged. I am sorry to say I never heard from the gentleman.

About a year ago, when the Trustees of the Sanitary District of Chicago made an arrangement with the Scherzer Rolling Lift Bridge Company for the construction of several bridges under the patents controlled by that company, the same old rumors started again, and I made up my mind to find out, if possible, whether there was any foundation for the reports or not. I naturally turned to the large library of scientific books we have in this city—the John Crerar Library. After I had once started properly it did not take me very long to find what I was looking for. The result of the search is, in my opinion, so interesting that I thought I could do no better than to bring it before the members of this Society and let you, gentlemen, judge for yourselves whether the type of bridge is really old or not.

In the third division of the second volume of the "Handbuch der Ingenieurswissenschaft"—a German publication of 1888, or five years prior to the time the first patents on bascule bridges were issued—there is a chapter on bascule bridges, which I have translated as closely as possible, and which, as it is only a short chapter, I shall take the liberty of reading to you:

"Bascule bridges have either a fixed or a movable axis of rotation. Like the draw-bridges, the bascule bridges turn around a horizontal axis." (A draw-bridge means here a structure like the tower bridge in London, or the bridge built by Mr. Geo. S. Morison here in Chicago close to the eight-track bridge over the Drainage Canal.) "But while this axis, in the case of draw-bridges, is placed at the end of the girders, it lies here close to the center of gravity of the whole moving mass. The proportion of the part in front and the part behind the point of support is found to vary from 1:6 to 1:1. The shorter tail portion receives the counterweight, which is usually arranged to bring the center of gravity a little in front of the point of support, so that the bridge has the tendency to close of its own accord. The opening of the bascule bridges is accomplished by pulling down the tail portion, for which purpose ropes, chains, or gear wheels, etc., may be used.

"The bascule bridges are divided in single and double leaf bridges, depending upon the use of only one or two leaves to bridge the opening.

"The bascule bridges are further classified as such with a fixed and with a movable axis of rotation. Those with a fixed axis are much oftener used and will consequently be treated more fully in this volume.

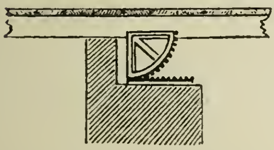
"The bascule bridges with movable axis of rotation occur in two types:

"1st. The axis of rotation, or the center of gravity in this case, moves parallel to itself along a straight line.

"2nd. The axis of rotation moves parallel to itself along a curve.

"In the first type the axis of rotation is replaced by toothed sectors whose centers coincide with the center of rotation, and whose circumference rolls on toothed racks which are placed on the side walls, so that the center of gravity of the whole system moves in a horizontal line. Such a bridge was built at Havre, in France, before 1824, by Lomblardie. It had a span of 13.2 meters (or about 40 feet), and a width of 5 meters (or about 16 feet). In this construction the end of the tail portion describes a cycloidal curve, and the required pit becomes shorter than with bridges that turn around a fixed axis. On the other hand, the movement of the bridge becomes more certain when a fixed pivot is used."

Fig. 30.



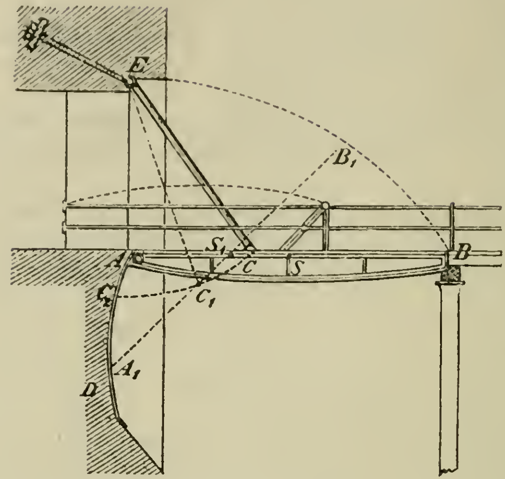
The sketch referred to does not show what method of operation was used in the Havre bridge.

As an example of the second type of bascule bridges, in which the axis of rotation moves parallel to a curve, the bridge by Ardagh is mentioned.

The drawing which is shown is a copy of a sketch found in the book mentioned, and I will continue reading the description as given:

"The girders, A B, whose center of gravity is in S, is supported by the rods, C E, in E. The rear end, A, carries a flanged roller, which moves along the guide curve, A D, during the operation of the bridge. The shape of this curve is such that the center of gravity, S, moves in a horizontal line, so that no mechanical work is required save that to overcome the friction." A clear method is also given by which this curve may be constructed.

Fig. 31.



It is clear to any engineer at all familiar with the various types of modern bascule bridges, that the bridge built by Lomblardie at Havre, and shown by the first drawing, is a crude outline of the type now quite familiar to us as the Scherzer Rolling Lift Bridge, and has the same kinematic elements, except for the operating machinery and the automatic locks.

The Ardagh bridge is nothing else than the Schinke type of bridge, as anyone can find out who gets the original drawings from the Patent office. He will find that the girders, A B, are exactly supported as shown here, the masonry being simply replaced by a tower.

The cuts shown are photographic reproductions of the illustrations in the original text.

DISCUSSION BY G. A. M. LILJENCRANTZ, M. W. S. E.

Extract from notes on Bridge Constructions from lectures in the Royal Technological Institute in Stockholm, Sweden, by Capt. A. M. Lindgren, of the Royal Engineer Corps, in the year 1866, by G. A. M. Liljencrantz, at that time a student at the Royal Technological Institute:

. . . . . Lately, however, preference has been given to counterbalance cast iron bridges similar to the two bridges across the new lock at Stockholm, which were completed in 1851 by Colonel Nils Ericson.

Each of these bascule bridges, which accommodate the traffic across the 32.8 feet wide lock chamber, consists of two leaves 27 feet 3 inches wide, each composed of eight cast iron girders of the form shown in Fig. 1. The leaves are operated by cranks open to view on the outside of each leaf. (Fig. 1 plan.) The machinery is fastened to the bridge itself and the segment, a, to the masonry. The shaft around which the bridge revolves is at X. The tail ends, Y, with counterweights move in masonry chambers.

To regulate the movement of the bridge when being opened or closed, a number of counterweights, Z, are placed on the tail arms, when the bridge is closed, but when opening the bridge the tail arms are relieved of these counterweights one after the other,

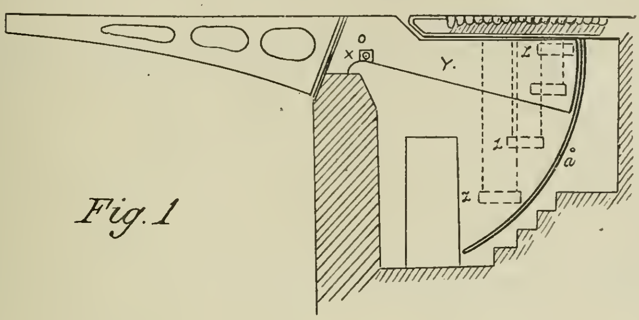
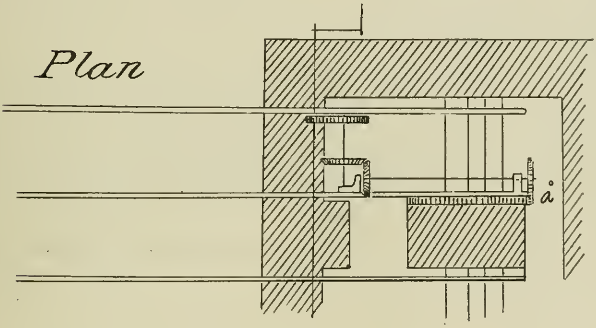


Fig. 1

Plan



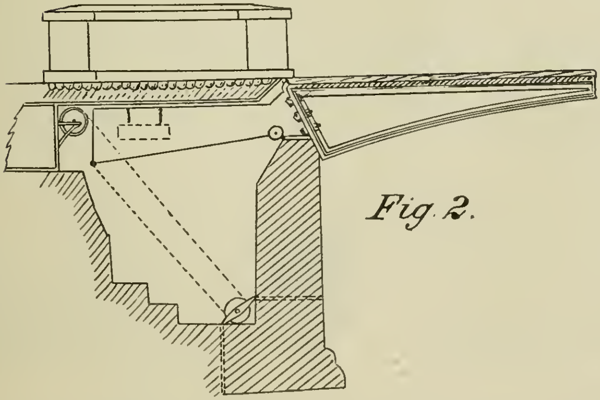


Fig. 2.

as the leaf is raised and the moment of the bridge proper is reduced. The release of the counterweights is accomplished in a very simple manner, the weight being fastened to the floor of the bridge by chains of different lengths, the chains keeping the weights suspended when the tail-end of the bridge is in its highest position.

Another illustration of a similar construction is the new bridge completed in 1863 over the canal in Gottenburg and constructed by Capt. J. Richert.

This bridge consists of three spans, namely, two fixed spans of 31 feet 8 inches, one at each end, and one movable center span with leaves of 25 feet 4 inches length. The fixed spans have a clear width between railings of 27 feet 6 inches, and the middle span a width of 25 feet 4 inches. All the spans are constructed as plate girders. Each leaf of the movable center span consists of six plate girders with one-fourth inch web plates and flanges 6½ inches wide of one-fourth inch metal. Each bridge leaf is braced transversely in three places, or has three cross braces of one-eighth inch plates strengthened by 2x2x¼ inch angles. The tail arms are made of cast iron and are connected to the ends of the plate girders, as shown in Fig. 2. The bridge turns around a shaft of 3¼ inches diameter.

Each leaf is opened by means of a chain running from a strut, which connects the ends of the tail arms, over a sheave in the bottom of the pit, to a drum fixed to the stiffeners at the ends of the fixed spans. This drum is put in motion by means of a windlass placed on the side of the bridge, turning the prolonged shaft of the drum by a pair of conical gears.

The movement of the bridge is regulated in a similar manner to that of the bridges at Stockholm.

THE TECHNOLEXICON.

The lack of a good technical dictionary is almost universally felt. All engineers have known of this want at one time or another. The Century Dictionary—comprehensive as it is—does not altogether supply this need. There have been attempts made in this line heretofore, but they lacked completeness. There are dictionaries in English of terms or words connected with the Science of Electricity. The Car Builders' Dictionary is very good as far as it goes, but it is limited in its scope. How often has an engineer, endeavoring to find what has been written by some German or French writer, been stopped in his laborious work, though aided, perhaps, by an ordinary German or French dictionary, because the book referred to did not contain the technical word he has met in his reading, and the meaning of which was needed to render his translation clear and intelligible.

There is a prospect of this need being supplied through the labors of the German Society of Engineers,—"Verein Deutscher Ingenieure." They have long felt (and lamented) this want of a comprehensive dictionary of technical words and phrases, and have decided upon collecting the material and publishing such a work.

To make it the more complete and valuable, this "Technolexicon" will be issued in three parts—one for each language,—English, German and French—each with the corresponding word in the other languages, as well as the definition,—thus:

I—German, English, French.
II—English, German, French.
III—French, German, English.

With such an arrangement, and providing that the work is as comprehensive as planned, this literary production will be a monument to the German Society of Engineers.

As a preliminary step the projectors issued Circular I, in July, 1900, which is here given, and which shows that the assistance from other societies in England, France and elsewhere is needed to carry out their plans.

VEREIN DEUTSCHER INGENIEURE.

TECHNOLEXICON:
TECHNICAL DICTIONARY
German-English-French.
Published by the
SOCIETY OF GERMAN ENGINEERS

BERLIN NW., July, 1900.
43, Charlottenstr.

CIRCULAR I.

German engineers recognize the urgent necessity of having a reliable technical dictionary, especially in the three principal languages, viz.: English, German, French. On account of this the "Society of German Engineers" (Verein deutscher

Ingenieure) has taken up the question how to produce such a dictionary. The Society would readily spend time and money for this purpose, if this aim could thereby be attained. But this will only be possible, if our colleagues in England, the United States, France, Belgium, Austria, Switzerland and Germany give their assistance. For this end we appeal to the technical and scientific societies at home and abroad. In case of consent we venture to suggest that the societies should select suitable members, by the aid of whom the editor of the dictionary, who will be appointed by our Society, would be brought into touch with such scientific and industrial men as are willing to furnish the technical expressions appertaining to their special branches.

It must however be mentioned, that the above detailed collaboration of the technical societies and the scientific and industrial circles is expected to be rendered gratuitously, as otherwise the expenses would become too heavy. On the other hand no monetary or other contribution to the work is demanded.

We beg to ask whether ——— ———— would be willing to assist as above explained in regard to the English part in the compilation of international technical dictionary.

Yours respectfully,
VEREIN DEUTSCHER INGENIEURE.
TH. PETERS.

A second circular has been sent out by this same society after they received some assurance of assistance from other societies and individuals, which circular (II) is here given, and which explains itself.

VEREIN DEUTSCHER INGENIEURE.

TECHNOLEXICON:
TECHNICAL DICTIONARY
German-English-French.
Published by the
SOCIETY OF GERMAN ENGINEERS

BERLIN (NW 7), March 1901.
Charlottenstr, 43.

CIRCULAR II.

In July, 1900, we sent a circular to a great number of technico-scientific societies at home and abroad as an invitation to co-operate with us in compiling a Technical Dictionary. Meanwhile we have many answers which approve our design and particularly recognize the urgent want of such a dictionary. We have secured the services of the well-known lexicographer, Dr Hubert Jansen, as editor, and the editorial office has been established in our house, Berlin (NW. 7), 49, Dorotheenstr.

Our object in forwarding this second circular is to express ourselves more fully about the co-operation (requested in our first circular) of societies, authorities, establishments, and individuals at home and abroad, and at the same time to answer a number of questions addressed to us by several parties concerned.

First of all we deem it necessary to emphasize once more that in inviting to co-operation we certainly do not ask for pecuniary contributions to the costs. The expenses necessary for the construction of the manuscript we intend to bear ourselves, and as to the printing, we shall later on arrange with one or more than one publisher. On the other hand, we expect the co-operation of the societies, authorities, etc., to be, as a rule, gratuitous.

This co-operation we understand thus, that the societies, authorities, establishments, etc., give us the names of contributors qualified for our work from among their members or functionaries. These collaborators will have to bring our editor of the dictionary into communication with such scientific and industrial circles as are able to supply the technical expressions and denominations used in the different technical branches; besides they will have to take part in noting down the technical words and phrases of their own specialty, and finally, when the manuscript is ready for the press, they will have to read the proofs.

Of our resolutions formed hitherto, which partly yet require the sanction of our general meetlng, we think it proper to communicate the following at present:

(a) Title. The dictionary will be called 'Technolexicon'; the technical dictionary German-English-French, published by the Society of German Engineers. We have chosen a title as short as possible and at the same time international, trusting that the work will soon be known everywhere under this name.

(b) Branches. The Technolexicon will comprehend all technical departments, especially those of the technical sciences, and those in which patents are granted. A detailed specification of these branches cannot yet be given.

(c) Languages. The Technolexicon will include the three languages: German, English, and French. From several parties concerned, additional wishes have been submitted to us, especially regarding the admission of the Italian and the Spanish language; we are, however, of the opinion that we must wisely restrict ourselves, bearing in mind the maxim: "Moderation makes the master."

(d) Arrangement of the languages, The Technolexicon will appear in 3 volumes: each volume will contain the three languages, viz.:

the I volume: German-English-French,
the II volume: English-German-French.
the III volume: French-German-English.

DER VEREIN DEUTSCHER INGENIEURE.
LEMMER, Chairman.
v. BORRES, Curator.
TH. PETERS, Director.

Among other societies to whom these circulars have been sent are the American Society of Civil Engineers and the Western Society of Engineers.

To bring this important matter more fully to the attention of the members of the W. S. E., with a view of securing their co-operation, the following circular was prepared and sent out to them:

WESTERN SOCIETY OF ENGINEERS

1737 MONADNOCK BLOCK

CHICAGO.

DEAR SIR:

Having been requested to assist in gathering data for the "Technolexicon" (or Technical Dictionary in German, English and French), now being compiled by the Society of German Engineers, the President of the Western Society of Engineers solicits the assistance of its members.

It is suggested that wherever any member has in mind, or meets in his work or reading any foreign technical* word, term or expression, the exact equivalent of which he does not know, he shall make a note thereof and hand it to the Secretary, who will either furnish a translation from some existing dictionary or enter it into the note book furnished for the "Technolexicon," and endeavor to obtain a translation for him When the member has an approximate understanding of the meaning, he is requested to note that also. Still more valuable service will be rendered if the member makes special efforts to collect such technical terms.

If the member has for his own use either a technical glossary or a list of foreign technical words, phrases or expressions, he is especially requested to furnish a list thereof to the Secretary.

When the member uses in his specialty some technical terms which he has reason to believe are not included in technical dictionaries, he is requested to send to the Secretary a list thereof, with definitions, descriptions or sketches, or, better

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*TECHNICAL.—"Of or pertaining to the mechanical arts, or any particular art, science, profes-"sion or trade: specially appropriate or characteristic of any art, science, professsion or trade, as a "*technical* word or phrase; a word taken in a technical sense; a *technical* difficulty; *technical* skill; "*technical* schools." CENTURY DICTIONARY.

still, with translations into German or French. It is suggested that one way of gathering such terms will be for the member to underscore them with red ink on a copy of the specifications and forms of contract which he uses, and to send the same to the Secretary, with such definitions or translations as he can furnish.

To serve as a basis for the compilation of the "Technolexicon," the German society particularly desires to obtain the titles of special trade dictionaries. It also desires price lists, catalogues, business announcements and advertisements which contain technical terms or expressions. Members are requested to send in such as they deem appropriate, with words underscored with red ink and with definitions if practicable.

When it is known that a different term is used in England to express the same thing, it will be desirable to append in brackets [American].

The Secretary will be furnished with several note-books, and will endeavor to classify the words appertaining to the several specialties of engineering.

J. H. WARDER,
Secretary W. S. E.

September 26, 1901.

The Secretary begs to state that copies of the circulars and instructions mentioned herein are on hand at the office of the Secretary of the W. S. E. for the use of those who will take hold and render some active assistance in this work.

It is hoped that the members of the W. S. E. will take some pains to assist in a work which is likely to be of material benefit to the profession at large as well as to themselves.

IN MEMORIAM.

FREDERICK HENRY DAVIES, M. W. S. E.

On the 21st day of June last this Society lost by death one of its valued members, Frederick Henry Davies, under peculiarly sad conditions. While proceeding to his work on a hand car, the unlooked for appearance of a construction train through a dense cloud of smoke that obscured the track obliged all on the car to leap from it. Mr. Davies, however, in attempting to remove the car from the track was struck by the train and received such serious injury that he never recovered consciousness and died a few days after. His wife had accompanied him, expecting to pick some strawberries while he should be engaged with his work, and she was forced to remain a helpless spectator while her husband was thus caught and killed.

At the time of his death Mr. Davies was resident engineer on the Baltimore & Ohio Railroad, with headquarters at Milford, Ind. Prior to his engagement with this company he had been engaged on various engineering works in the middle west, and had acquired a reputation as a most careful and reliable engineer. His first work was with the Illinois Central Railroad Company in 1868, he remaining with that company for several years. From the Illinois Central he went to the Chicago, Burlington & Quincy Railroad. He afterwards was in the employ of the city of Chicago, and held a responsible position in the sewer department for several years until a "reform" administration demanded his place for a member of its own party. Subsequently he was connected with several different corporations and railroads in their engineering departments. He became a member of this Society April 6, 1892.

Mr. Davies was a student of engineering literature and possessed a wide fund of information on the varied branches of his profession. He was unobtrusive in manner and of a temperament that tended to keep him in the background, while some persons less competent than himself appeared more prominently at the front. Those who knew him well appreciated his sterling qualities of head and heart, and these will recognize his unwavering devotion to what he considered his duty in the attempt to save the property of his employer and the lives of his fellow-employes which cost him his own life.

Mr. Davies was born in Strout, England, December 28, 1846; came to the United States in 1868, and died June 21, 1901. His widow and three sons survive him.

L. P. Morehouse,
H. W. Parkhurst,
G. A. M. Liljencrantz.

JAMES F. LEWIS, M. W. S. E.

James Frederick Lewis was born at Blandford, Mass., May 26th, 1840; died at Boston, Mass., July 23d, 1901.

He was educated in the schools of his native town until fourteen years of age, when with his parents he moved to Meriden, Conn., and later to Bloomfield, N. J. He responded to the first call for volunteers in 1861, enlisting in the Third Connecticut Volunteers as a private. He took part in the first battle of Bull Run, where he was wounded, and subsequently mustered out of the service in consequence of it.

In 1862 he married, and later moved to Westfield, Mass., where he associated himself with the two Rand Brothers in a partnership known as Rand, Lewis & Rand, manufacturing whips. This firm contributed largely toward making Westfield the principal whip producing point in America. In 1876 he became superintendent for the Manhattan Mining Company of its iron ore mines near Amenia, N. Y. This position he resigned in 1881 to accept the superintendency of the coal and coke department of the Pennsylvania & Virginia Coal & Iron Company at Quinnemont, W. Va. This company operated a blast furnace at that point and also one near Staunton, W. Va. In 1884 he again associated himself with the Rands, who had organized and established the Rand Drill Co. Mr. Lewis went to New York, where he remained until 1892, when he removed to Chicago and started and conducted the Western branch of the company.

In 1890 the Canadian Rand Drill Company was organized with Mr. Lewis as president. About 1898 the requirements of the Canadian Company compelled him to reside in that country. Their shops had burned. Mr. Lewis designed and erected new ones at Sherbrooke, where he had his home at the time of his death.

He was an indefatigable worker, and his health, which had been somewhat impaired while living in Chicago, gave way, and he realized at last that he must take a rest, and decided to go South. While passing through Boston with his family he was stricken with pneumonia. He rallied but did not recover from the attack, and after lingering for about three months, died. His remains were buried at Meriden, Conn. He left a wife and adopted daughter.

Mr. Lewis was a member of the Grand Army of the Republic; American Institute of Mining Engineers; American Society of Civil Engineers (Associate); American Society of Mechanical Engineers; Western Society of Engineers; Iron & Steel Institute; Canadian Mining Institute, and many railway and other technical clubs. His social clubs were: the Engineers, New York; Technical, Chicago; Halifax and City Clubs, Halifax, and St. George Club, Sherbrooke.

Mr. Lewis could not be connected with a business, technical or social organization, without taking an active and prominent part in its affairs; and possessing keen insight and sound judgment, his services were of great value. He also had the faculty of drawing men to him; thus he controlled through their hearts as well as intellects. His acquaintance extended to nearly all civilized countries.

Mr. Lewis was an ardent citizen; hence, while never seeking office, he took an active part in public affairs, and enjoyed the confidence of many prominent American statesmen.

He was a devoted husband, and not having children of his own, adopted a niece who knew him only as a loving father.

The Western Society of Engineers had in Mr. Lewis one of its most loyal and active members, and can sincerely join its sister organizations in grief over his loss.

R. W. Hunt.
Alfred Noble.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING, September 4, 1901.

A regular meeting (No. 454) of the Western Society of Engineers was held in the hall on the evening of September 4th, 1901.

The meeting was called to order with 1st Vice President Finley in the chair, at 8:30 P. M., with sixty-eight members and guests present.

The minutes of the meetings held June 5th and 26th were read and adopted.

On behalf of the Board of Direction, the Secretary read the names of those who had been elected into membership, as follows:

July 2nd —

Wm. L. Abbott, Chicago, Active.
Dr. L. L. Hubbard, Houghton, Mich , Associate.
J. B. Girand, Williams, Arizona, Active.
C. B. Burdick, Chicago, Active.
B. J. Sweatt, Mason City, Iowa, Active.
H. H. Jackman, Chicago, Active.
Chas. G. Ludlow, Chicago, Active.
A. V. Abbott, Chicago, Active.
T. C. Phillips, Chicago, Junior.

August 8th—

Wm. S. Monroe, Chicago, Active.
V. C. Suckow, Chicago, Active.

September 4th—

Jno. G. Bergquist, Chicago, Active.
Edgar Murphy, Galesburg, Ill., Active.
Chas. W. E. Clark, Chicago, Junior.
R. C. Huston, Chicago, Active.
Jas. J. Taylor, Truro, N. S., Active.
F. W. von Oven, Aurora, Ill , Active.
G. W. Smith, Chicago, Active.

Also the names of new applicants presented at the Board meeting, September 4th, as follows:

Geo. M. Brill, M. E., Chicago, Active.
Chas. E. Ferreira, Chicago, Active.
Wm. M. Torrance, Grand Rapids, Wis., Active.

There were no reports presented from the Standing Committees, but the Secretary announced the death of a valued member, Mr. James F. Lewis, of Sherbrooke, Canada.

There being no other business before the Society, the Chairman announced the paper for the evening from Mr. W. H. Pratt, of the Illinois Steel Company, on "Modern Practice in Bridge Shop Work."

There was a free discussion of this subject after the reading of the paper, in which Messrs. Ziesing, Horton, Finley, Bainbridge, Bley, Schaub, Pratt, Modjeski and Allen took part.

The meeting then adjourned.

SPECIAL MEETING, Sept. 18, 1900.

A special meeting (No. 455) of the Western Society of Engineers was held on the evening of September 18, 1901, with fifty-five members and guests present.

The meeting was called to order by President Chanute at 8:40 P. M., who presented the subject of Aerial Navigation, and then introduced Mr. Wilbur Wright, of Dayton, Ohio, who addressed the Society on some "Late Gliding Experiments," applying the term "gliding" to moving through the air, supported by an extended surface, which, like a kite, was buoyed up by the pressure of a current of air, as the wind. These gliding experiments were made against the wind, and usually from the summit of a hill.

The address was illustrated with a number of lantern slides, which showed various forms of gliding machines, and also some views of a machine, with an operator, passing through the air.

The meeting adjourned at 10:40 P. M.

REGULAR MEETING, Oct. 2, 1901.

The regular meeting (No. 456) of the Western Society of Engineers was held in the hall on the evening of October 2nd, 1901.

The meeting was called to order at 8:30 by 1st Vice President Finley, with about fifty-five members and guests present.

The Secretary read the minutes of the regular meeting of September 4th and the special meeting of September 18th, which were accepted.

The Secretary also read a report from the Board of Direction of their meeting held September 3rd. Those elected to active membership are:

Geo. M. Brill, Chicago.
Chas. E. Ferreira, Chicago.
Wm. M. Torrance, Grand Rapids, Wis.

The following names were presented as candidates for membership:

H. W. Swanitz, Tamaroa, Ill, Junior.
Robt. F. Wentz, Nazareth, Pa., Active.
J. J. Giaver, Chicago, Active.
E. E. Amory, Chicago, Active.
Jno. H. Frederickson, Chicago, Active.
James F. Case, Manila, P. I., Active.
John V. Schafer, Chicago, Active.
Ernest F. Smith, Chicago, Active.
Richard McCullough, Chicago, Active.
Luther V. Rice, Chicago, Active.

The death of one of our members, Mr. W. J. Yoder, was announced.

The Chairman then introduced Mr. J.V. Schafer, of the Link-Belt Machinery Company, who gave a lecture on the "Washing of Bituminous Coals by the Luhrig Process."

The meeting adjourned at 9:45 P. M. J. H. Warder, *Sec'y.*

EXCURSION ON OCTOBER 5th, 1901.

Through the courtesy of the Chicago, Burlington & Quincy Railroad Company, a special train, consisting of five vestibule chair cars and one box car—so called on account of carrying the lunch boxes—was placed at the disposal of the Society for the purpose of an outing, on Saturday, October 5th.

About 200 members, their families and friends, availed themselves of the opportunity and at 9:20 A. M. the train left the depot. By the kind invitation of Mr. F. W. Matthiessen, the owner of Deer Park, the party first took in refreshments and later the scenery at this beautiful place. Everybody having remembered to bring along his or her appetite, the Committee was not hampered by the care of any leavings. After a couple of hours of enjoyment at this delightful spot, the caterer proceeded to count the spoons and forks, and the party returned to the train, which then sped on, on the homeward stretch, making a short stop to see the "wheels go round" at the Spring Valley Coal Mine, and in the best of spirits, soberly speaking, the party returned to the city at 7:00 P. M.

"SMOKER" ON OCTOBER 16th, 1901.

On Wednesday, the 16th of October, 1901, a "Smoker," etc., was arranged for by the Entertainment Committee in the Society's rooms.

Some forty-five members attended, some to smoke and chat, others to find out what the "Etc." was. A letter from Mr. R. P. Morgan, a resident—not temporary visitor—of Dwight, Ill., was received and read. He expressed his regrets at not being able to attend, not being a smoker, and, referring to the dangers of the smoke habit, cited a personal friend who always smoked except when eating or sleeping, who, to all appearances, was in the best possible mental condition, but who, in January next, would be 100 years old.

Messrs. Isham Randolph and William J. Karner told some choice stories, and an informal paper entitled, "Professions and Professional Men," was read by Mr. Liljencrantz.

Having partaken of, and presumably enjoyed, the "Etc.," the meeting adjourned at 10:15 P. M.

G. A. M. L.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

Western Railway Club, Chicago, 2 cloth bound volumes, Official Proceedings of the Western Railway Club, 1899-1900. Official Proceedings of the Western Railway Club, 1900-1901.

E. E. R. Tratman, 1 volume, cloth, Beeson's Marine Directory of the Northwest Lakes.
1 pamphlet, Administration Report of the Railways in India, 1900.
1 pamphlet, Proceedings 18th annual convention, Road Masters' Association of America.
1 pamphlet, Sixth Annual Report, 1900, Boston Transit Commission.
1 volume, cloth, U. S. Department of Agriculture, Division of Forestry, Metal vs. Wooden Ties, by E. E. R. Tratman and B. E. Fernow.
8 pamphlets, Papers relating to the History of various English Railways, by C. E. Stretton, C. E.

Westinghouse Air Brake Co., Pittsburgh, 1 volume, cloth bound, The Effect of Brakes upon Railway Trains, by Capt. D. Galton.

Otis F. Clapp, City Engineer, Providence, R. I., 1 pamphlet, Annual Report, City Engineer, 1900.

Thos. W. Gibson, Director Bureau of Mines, Toronto, Canada, 1 pamphlet, Report Bureau of Mines (Toronto), for 1901.

Maj. Jas. R. Willett, Chicago, seven bound books, American and European Railway Practice, by A. L. Holley, 1861, 1 vol.
Railway Machinery, by D. K. Clarke, 1855, 2 vols.
Water Supply for Cities and Towns, by Wm. Humber, 1879, 1 vol.
The Pennsylvania Railroad, James Dredge, London, 1879, 1 vol.
Filtration of River Waters, by Jas. P. Kirkwood, (Van Nostrand), 1869, 1 vol.
The Brooklyn Water Works, New York, 1867, 1 vol.

Geo. F. Mills, Mgr. Niles Tool Works, Western Union Building, Chicago, 1 vol., cloth bound, Illustrated Catalogue of Machine Tools. Niles Tool Works, Hamilton, Ohio.

Secretary, American Society of Mechanical Engineers, New York, 2 vols., paper, Transactions American Society Mechanical Engineers (XX, 1899; XXI, 1901), in exchange for W. S. E Journal.

Board of Railroad Commissioners, State of Iowa (Des Moines), 1 vol., cloth. Report, 1900, of Iowa State R. R. Commissioners.

S. H. Ashbridge, Mayor of Philadelphia, 1 vol., cloth. 14th Annual Report, Dept. of Public Works, Philadelphia, 1900.

J. F. Steward, Sheridan Road, Chicago, 1 vol., cloth. Official Retrospective Exhibit of the Development of Harvesting Machinery, Paris, 1900.

Liverpool Engineering Society, 1 pamphlet, Vol. XXI, Transactions 26th session, 1900.

Canadian Mining Institute, Montreal, 1 pamphlet, Vol. IV, Journal, Proceedings, August, 1900, March, 1901.

American Institute of Mining Engineers, 1 pamphlet, Transactions American Institute of Mining Engineers, Vol. XXX, 1900.

W. S. Bates, 1 vol., cloth, 13th Annual Report Indiana State Geologist, 1883.

Chief Engineers, Washington, D. C., 1 vol , cloth, Report Board of Engineers on Testing Hydraulic Cements.

"Compressed Air," New York, 1 vol., bds., "Pumping by Compressed Air," by E. A. Rix.

B. F. Sturtevant Co., Boston, Mass., 1 pamphlet, Catalogue No. 118, Steam Hot Blast Apparatus.

Department of the Interior, Washington, D. C., 1 vol., cloth, Abstract of the Eleventh Census, 1890.

J. B. Dickson, C. & N. W. Ry., Sterling, Ill., Sec'y Roadmasters' Association of America, 14 pamphlets, Proceedings of 5th to 8th inclusive, and 10th to 18th inclusive, annual conventions.

New York State Board of Health, 2 vols., cloth, 20th Annual Report for 1899, with maps.

Illinois Steel Co., Chicago, 1 vol., morocco, Description of Works, List of Shapes, Rails, Specifications, etc.

Standard Pneumatic Tool Co., Chicago, Trade Catalogue "F" for 1901.

The Q. & C. Company, Chicago, Trade Catalogue of Pneumatic Tools, 1901.

American Radiator Co., Chicago, Trade Catalogue of American Radiators, 1901.
Trade Catalogue Radiator Boilers, 1901.
Trade Catalogue Ideal Fitter, 1900-1901.

P. H. & F. M. Roots Co., Connersville, Ind., Trade Catalogue Rotary Pressure Blower, 1898.
Trade Catalogue Rotary Force Pumps, 1899.

E. W. Sluyter, Clerk and Supt., The Municipal Commission, Herkimer, N. Y., six pamphlets, 1st to 6th inclusive, Annual Reports, 1896-1901.

United Telpherage Co., New York City, Trade Catalogue, Conveying Machinery. Circular No. 16, 1901.

J. R. Thompson, City Engineer, Mankato, Minn., Annual Reports for 1900 of City Engineer, Supt. of Parks and Health Officer.

Joseph B. Rider, C. E., South Norwalk, Conn., one leather bound book with flap, "The Little Engineer." Pocket-book of engineering data.

Dr. Jas. A. Egan, Secretary Illinois State Board of Health, one cloth bound vol., Sanitary Investigation of the Illinois River and its Tributaries, 1901.

S. S. Boies, Engineering Record, New York, one cloth bound vol., Water Works for Small Cities and Towns, by John Goodell.

Bullock Electric Mfg. Co., Cincinnati, various bulletins of Electrical Machinery.

American Railway Engineering and Maintenance of Way Association, Proceedings first and second Annual Conventions, 1900-1901; also Bulletin, Vol. II, No. 1, November, 1900.

Lyman E. Cooley, Chicago, Report of L. E. Cooley on the Water Power of the Des Moines Rapids of the Mississippi River, 1901.

Department of Agriculture, Washington, D. C., one pamphlet on "Forest Extension in the Middle West," by Wm. L. Hall.

G. P. Loomis, Chicago, Barber Asphalt Paving Co., Trade Catalogue for 1900.

BOOK NOTES.

A Practical Treatise of Segmental and Elliptical, Oblique or Skew Arches. Setting forth the principles and details of construction in clear and simple terms. By George Joseph Bell, County Surveyor and Bridgemaster, of Cumberland, England. Sold by Spon & Chamberlin, 12 Cortlandt St., New York. 7½x10⅜ inches; pp. 125; illustrated.

The problem of the skew arch is not a common one in the practice of the engineers of this country, but as the use of the stone arch is becoming more common it follows that designs of skew arches will be more in demand. Perhaps we cannot do better, in giving an idea of the scope of this work, than to quote from the preface:

"The object of the writer in making this attempt is to place reliable data, which can be readily understood, in the hands of practical workmen, so as to render the building of oblique arches as simple as the building of an ordinary square arch. No attempt is made to instruct highly educated engineers, to whose hands the problem has hitherto been almost exclusively confined, but this essay has been solely written for the purpose of making the subject intelligible to the average working mason."

We think the author has succeeded in his purpose; but the intelligent workman is not the only one to whom the book will be a great help. The engineer will find it a handy volume.

The projection of the arch, making of drawings, construction and use of templets, setting up and erecting of bridges, are all gone into detail and illustrated by diagrams and figures. A number of photographic views of the Sickergill oblique arch at different stages of construction, with explanatory text, helps materially in the understanding of the method of procedure. The first part of the book is entirely free from the mathematics of the oblique arch, which is reserved for another chapter. Tables are given from which may be derived the theoretical dimensions of the oblique arches from 30 to 70 degrees obliquity, advancing by five degrees, and of from 10 to 50 feet span, advancing by five feet, and of any desired width. There is also a table of adjusted multipliers for twisting rules, and in addition many other tables of information useful to the student of the oblique arch. The book is quite complete, and, we believe, the simplest and best of anything yet published in this line.

E. H. R.

A Brief History of Mathematics. An authorized translation of Dr. Karl Fink's "Geschichte der Elementar-Mathematik." By Wooster Woodruff Beman, Professor of Mathematics in the University of Michigan, and David Eugene Smith, Principal of the State Normal School, Brockport, N. Y. Chicago: The Open Court Publishing Co., 1900. 321 pages, including biographical notes. Price, cloth, $1.50.

As the title-page of the volume explains, it is purely a history of mathematics.

Starting with the number system and number symbols, a record is given of the most primitive systems of enumeration. In natural sequence the discussion of arithmetic follows and is divided into three periods; the first period being the arithmetic of the oldest nations down to the time of the Arabs; the second, from the eighth to the fourteenth century, and the third, the fifteenth to the nineteenth century. In each of these periods the arithmetic of whole numbers, the arithmetic of fractions and applied arithmetic, are historically treated.

Algebra is the next subject, and is under a subdivision similar to that used in arithmetic.

The history of geometry is divided into five periods, commencing with the Egyptians and Babylonians, and in conclusion there is a brief account of the development of trigonometry. In the end of the volume there are several pages of biographical notes, with the names that are found in the body of the book, alphabetically arranged.

This work is evidently not intended to be an exhaustive discussion of the whole subject of mathematics, but is, as its name implies, a most interesting history, showing great research on the part of the authors. T. C. I.

Rider's Little Engineer. A Pocket Book of Engineering and other data. By Joseph B. Rider, C. E. Published by the author, in South Norwalk, Conn. Size, 7x4¼ inches, with flap, 480 pages. Price, $3.00.

As the author states in his preface, the book is not intended as an instructor, but rather for the reference of engineers and officials on points coming up in connection with their professional duties, which may be for the time forgotten, and for this purpose it is admirably adapted.

The book contains much that is valuable in the way of tables and data regarding road and masonry construction, and the explanations and descriptions are written in a clear, concise and pleasing style. Commencing with the tables of weights, measures, squares, cubes, areas, degrees, etc., which are always useful, the author prints a copy of the specifications for public highway improvements used by the State of New York, supplementing this with numerous useful notes on road and masonry construction taken from his own experience. There is an extensive article devoted to the uses and application of water, with tables of velocities, power, etc., under varying conditions, and a very interesting as well as instructive chapter on the electrolysis of water mains.

The subject of water-wheels and steam pumps is also treated in a commendable manner, and concludes with an able and practical review on the efficiency and construction of several filtering plants now in successful operation.

On the whole, the book is a valuable companion for the engineer or official connected with the construction and maintenance of roads, dams and hydraulic plants. V. C. S.

Pumping by Compressed Air. By Edward A. Rix, M. E. 8vo, 35 pages, illustrations and diagrams. Price, 75 cents. Published by "Compressed Air," 26 Cortlandt st., New York.

This book is a reprint of a paper read before the Technical Society of the Pacific Coast, August 3rd, 1901, and published in the "Journal of the Association of Engineering Societies."

The paper discusses various methods of pumping by compressed air, touching on points which have not been generally considered, and is a plea for the designing of machinery especially adapted to the use of compressed air, thus resulting in better economy. "The economical expansion of air must be the exact reverse of the economical compression of air." The author points out the fact that much attention is given to the latter by the manufacturers of air compressors, but no thought is given to the machine to be driven by the expansion of the compressed air. Pumps designed for the use of steam are put to this use, which, of course, is not an efficient arrangement. Some economical arrangements are then suggested and the pumps are discussed under the following classification:

Displacement pumps for full pressure only.
Displacement pumps using expansion.
Direct acting pumps for full pressure only.
Direct acting pumps using expansion.
Air lift pumps and air lift pumps combined with displacement chambers.
Pumps operated by independent motors.

The comparison of values of the various systems of pumping by these means is well shown.

The action of each class of pump is described, and the advantages and disadvantages of the system shown. A great advantage of the second class over the first in a saving of expansive energy is pointed out, and it is stated that this system should be twice as economical as the first. Except for special purposes, the author does not recommend the use of the third class; but the fourth class, discussing compound or multi-cylinder pumps, the most useful, is interestingly and fully treated. There is a description of a system of combination of displacement and air lift pumping, and accounts of several tests of the latter system, also a table showing the first record of results in the history of air lift pumping.

The book contains tables giving the records of tests of compressed air pumps, and tables giving the results of experiments and requirements of air lift pumping. The subject is also discussed theoretically, and there are numerous diagrams showing work done in cylinder and a graphical presentation of one cycle of operation.

The arrangement of the matter in the book might be improved upon. Pumping by compressed air, by the use of direct acting pumps especially, is a subject upon which there is not much literature, and therefore the book will be found to be of interest and value. H. M. E.

Water Works for Small Cities and Towns. By John Goodell. A Manual of the requirements and construction of water systems under varying conditions. Engineering Record, New York. 8 vo., cloth; 286 pages including index. Price, $2.00.

This work consists of twenty chapters describing the methods of using surface water, ground water, spring and well supplies. Under the heading of Surface Water the author gives a lucid description of the methods employed in surveying, and for calculating the capacities of small watersheds, and a report on the characteristics of the watersheds controlled by the Boston Water Board, with an article on the use of weirs and of chemical analysis.

The subject of Dams and Reservoirs is treated in a lengthy and instructive manner, explaining the construction of earth, timber and masonry dams, and including a chapter on the minor details of reservoirs. The specifications and descriptions for the designing of dams are written in a clear and practical manner and are well worth reading, giving many valuable pointers regarding this class of work.

The chapter on the Special Features of River and Pond Supplies is very interesting as well as instructive, describing the effect of storage on water and the odors due to different microscopic organisms, which has been taken largely from G. C. Whipple's "Microscopy of Drinking Water."

Following this, the author devotes five chapters to the description and explanation of uses, capacities and characteristics of Springs and Wells of different kinds, giving lengthy accounts of the methods of sinking wells and the numerous obstacles encountered in connection with this work.

A chapter on Pumps gives considerable information on capacities and power required under varying conditions. The operation and use of the air-lift system is given in a detailed manner, including a table of tests made at Indianapolis. A description of Pumping Stations of the smaller type is also given, and a separate chapter on Intakes and Intake Pipes.

Clarification and Purification is the heading of a very well written article on Turbidity, and includes descriptions and data pertaining to the use of gravity and mechanical filters.

The Pipe System is treated in three chapters, with numerous notes and memoranda on the flow of water in pipes; on standpipes, their use and substitutes; and the effect of small street mains. This is a very useful and instructive section of the book.

The book concludes with a very ably written article on the maintenance and financial departments of Waterworks Plants.

One valuable feature of the work is the author's foresight in supplementing all his descriptions with the name of the book and author, which treats of the special subject referred to, in the best and most thorough manner. V. S. S.

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From the dues of each member $2.00 is set aside as a subscription to the JOURNAL.

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CXXXII.

SOME AERONAUTICAL EXPERIMENTS.

Mr. Wilbur Wright, Dayton, O.

Presented September 18, 1901.

INTRODUCTION BY PRESIDENT CHANUTE.

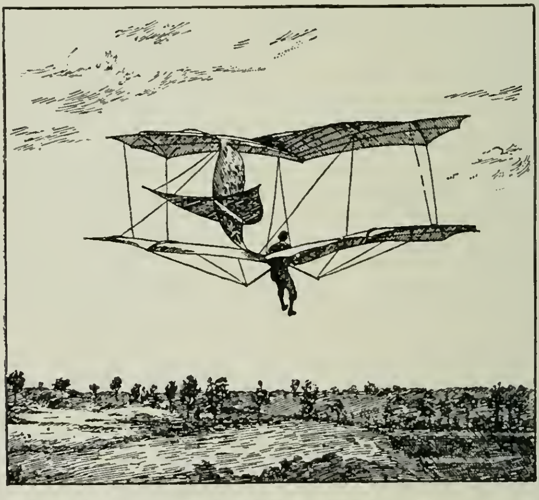
Engineers have, until recent years, fought shy of anything relating to aerial navigation. Those who ventured, in spite of the odium attached to that study, to look into it at all, became very soon satisfied that the great obstacle in the way was the lack of a motor sufficiently light to sustain its weight and that of an aeroplane, upon the air. Fifteen years ago the lightest steam motor was the marine engine weighing 60 pounds to the H. P., while the gas engine weighed very much more; the locomotive weighed 200 pounds per H. P. During the past fifteen years a great change has taken place. Steam motors have been produced weighing only 10 pounds per horse power, and gas engines have been lightened down to 12½ to 15 pounds per horse power, so that the status, so far as engineers are concerned, is very greatly changed, and there is some hope that, for some limited purposes at least, man will eventually be able to fly through the air. There is, however, before that can be carried out—before a motor can be applied to a flying machine—an important problem to solve—that of safety or that of stability.

I had the honor of telling you, some four or five years ago, something about the progress that had been made up to that time. Since then further advances have been make by two gentlemen from Dayton, Ohio,—Mr. Wilbur Wright and Mr. Orville Wright, who tried some very interesting experiments in October, 1900, about a year ago. These experiments were conducted on the sea shore of North Carolina, and were again resumed last July. These gentlemen have been bold enough to attempt some things which neither Lilienthal nor Pilcher nor myself dared to do. They have used surfaces very much greater in extent than those which hitherto had been deemed safe, and they have accomplished very remarkable results, part of which it was my privilege to see on a visit which I paid to their camp about a month ago.

I thought it would be interesting to the members of this society to be the first to learn of the results accomplished, and therefore, I have the honor of presenting to you Mr. Wilbur Wright.

The difficulties which obstruct the pathway to success in flying machine construction are of three general classes: (1) Those which relate to the construction of the sustaining wings. (2) Those which relate to the generation and application of the power required to drive the machine through the air. (3) Those relating to the balancing and steering of the machine after it is actually in flight. Of these difficulties two are already to a certain extent solved. Men already know how to construct wings or aeroplanes, which when driven through the air at sufficient speed, will not only sustain the weight of the wings themselves, but also that of the engine, and of the engineer as well. Men also know how to build engines and screws of sufficient lightness and power to drive these planes at sustaining speed. As long ago as 1893 a machine weighing 8,000 lbs. demonstrated its power both to lift itself from the ground and to maintain a speed of from thirty to forty miles per hour; but it came to grief in an accidental free flight, owing to the inability of the operators to balance and steer it properly. This inability to balance and steer still confronts students of the flying problem, although nearly ten years have passed. When this one feature has been worked out the age of flying machines will have arrived, for all other difficulties are of minor importance.

The person who merely watches the flight of a bird gathers the impression that the bird has nothing to think of but the flapping of its wings. As a matter of fact this is a very small part of its mental labor. To even mention all the things the bird must constantly keep in mind in order to fly securely through the air would take a considerable part of the evening. If I take this piece of paper, and after placing it parallel with the ground, quickly let it fall, it will not settle steadily down as a staid, sensible piece of paper ought to do, but it insists on contravening every recognized rule of decorum, turning over and darting hither and thither in the most erratic manner, much after the style of an untrained horse. Yet this is the style of steed that men must learn to manage before flying can become an every day sport. The bird has learned this art of equilibrium, and learned it so thoroughly that its skill is not apparent to our sight. We only learn to appreciate it when we try to imitate it. Now, there are two ways of learning how to ride a fractious horse: one is to get on him and learn by actual practice how each motion and trick may be best met; the other is to sit on

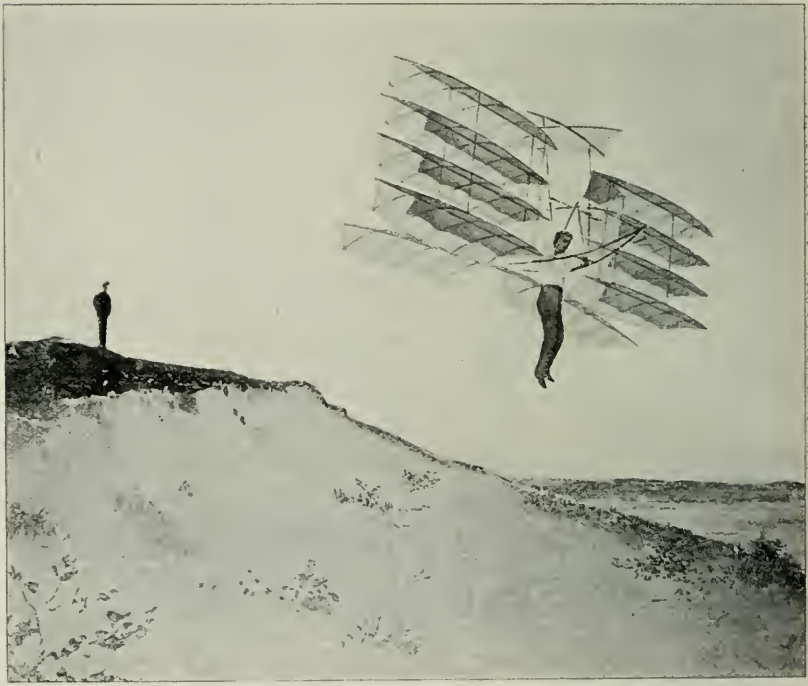


Lilienthal's Machine.

a fence and watch the beast awhile, and then retire to the house and at leisure figure out the best way of overcoming his jumps and kicks. The latter system is the safest; but the former, on the whole, turns out the larger proportion of good riders. It is very much the same in learning to ride a flying machine; if you are looking for perfect safety, you will do well to sit on a fence and watch the birds; but if you really wish to learn, you must mount a machine and become acquainted with its tricks by actual trial.

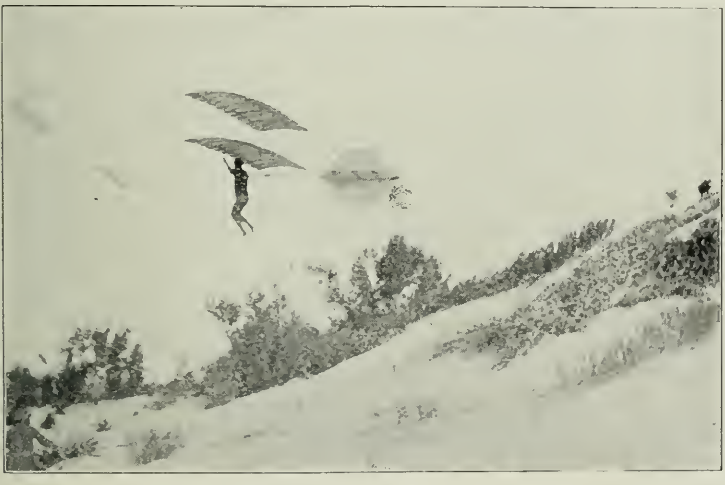
Herr Otto Lilienthal seems to have been the first man who really comprehended that balancing was the *first* instead of the *last* of the great problems in connection with human flight. He began where others left off, and thus saved the many thousands of dollars that it had theretofore been customary to spend in building and fitting expensive engines to machines which were uncontrollable when tried. He built a pair of wings of a size suitable to sustain his own weight, and made use of gravity as his motor. This motor not only cost him nothing to begin with, but it required no expensive fuel while in operation, and never had to be sent to the shop for repairs. It had one serious drawback, however, in that it always insisted on fixing the conditions under which it would work. These were, that the man should first betake himself and machine to the top of a hill and fly with a downward as well as a forward motion. Unless these conditions were complied with, gravity served no better than a balky horse—it would not work at all. Although Lilienthal must have thought the conditions were rather hard, he nevertheless accepted them till something better should turn up; and in this manner he made some two thousand flights, in a few cases landing at a point more than a thousand feet distant from his place of starting. Other men, no doubt, long before had thought of trying such a plan. Lilienthal not only thought, but acted; and in so doing probably made the greatest contribution to the solution of the flying problem that has ever been made by any one man. He demonstrated the feasibility of actual practice in the air, without which success is impossible. Herr Lilienthal was followed by Mr. Pilcher, a young English engineer, and by Mr. Chanute, a distinguished member of the society I now address. A few others have built machines, but nearly all that is of real value is due to the experiments conducted under the direction of the three men just mentioned.

The balancing of a gliding or flying machine is very simple in theory. It merely consists in causing the center of pressure to coincide with the center of gravity. But in actual practice there seems to be an almost boundless incompatibility of temper which prevents their remaining peaceably together for a single instant, so that the operator, who in this case acts as peacemaker, often suffers injury to himself while attempting to bring them together. If a wind strikes a vertical plane, the pressure on that part to one side of the center will exactly balance that on the other side, and the part above the center will balance that below. This point we call the center of pressure. But if the plane be slightly inclined, the pressure on the part nearest the wind is increased, and the pressure on the other part decreased, so that the center of pressure is now located, not in the center of the surface, but a little toward the side which is in advance. If the plane be still further inclined the center of pressure will move still farther forward. And if the wind blow a little to one side, it will also move over as if to meet it. Now, since neither the wind nor the machine for even an instant maintains exactly the same direction and velocity, it is evident that the man who would trace the course of the center of pressure must be very quick of mind; and he who would attempt to move his body to that spot at every change must be very active indeed. Yet this is what Herr Lilienthal attempted to do, and did do with most remarkable skill, as his two thousand glides sufficiently attest. How-



Chanute's Multiple-Wing Machine.

ever he did not escape being overturned by wind gusts several times, and finally lost his life through a breakage of his machine, due to defective construction. The Pilcher machine was similar to that of Lilienthal, and like it, seems to have been structurally weak; for on one occasion, while exhibiting the flight of his machine to several members of the Aeronautical Society of Great Britain, it suddenly collapsed and fell to the ground, causing injuries to the operator which proved sadly fatal. The method of management of this machine differed in no important respect from that of Lilienthal, the operator shifting his body to make the centers of pressure and gravity coincide. Although the fatalities which befell the designers of these machines were due to the lack of structural strength, rather than to lack of control, nevertheless it had become clear to the students of the problem that a more perfect method of control must be evolved. The Chanute machines marked a great advance in both respects. In the multiple wing machine, the tips folded slightly backward under the pressure of wind gusts, so that the travel of the center of pressure was thus largely counterbalanced. The guiding of the machine was done by a slight movement of the operator's body toward the direction in which it was desired that the machine should go. The double deck machine built and tried at the same time marked a very great structural advance, as it was the first in which the principles of the modern truss bridges were fully applied to flying machine construction. This machine in addition to its greatly improved construction and general design of parts

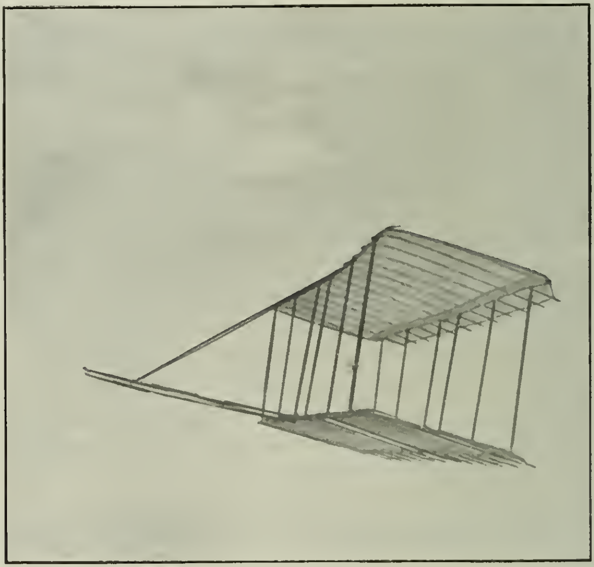


Chanute's Double-Deck Machine.

also differed from the machine of Lilienthal in the operation of its tail. In the Lilienthal machine the tail, instead of being fixed in one position, was prevented by a stop from folding downward beyond a certain point, but was free to fold upward without any hindrance. In the Chanute machine the tail was at first rigid, but afterward, at the suggestion of Mr. Herring, it was held in place by a spring that allowed it to move slightly either upward or downward with reference to its normal position, thus modifying the action of the wind gusts upon it, very much to its advantage. The guiding of the machine was effected by slight movements of the operator's body, as in the multiple wing machines. Both these machines were much more manageable than the Lilienthal type, and their structural strength, notwithstanding their extreme lightness, was such that no fatalities, or even accidents, marked the glides made with them, although winds were successfully encountered much greater in violence than any which previous experimenters had dared to attempt.

My own active interest in aeronautical problems dates back to the death of Lilienthal in 1896. The brief notice of his death which appeared in the telegraphic news at that time aroused a passive interest which had existed from my childhood, and led me take down from the shelves of our home library a book on "Animal Mechanism" by Prof. Marey, which I had already read several times. From this I was led to read more modern works, and as my brother soon became equally interested with myself, we soon passed from the reading to the thinking, and finally to the working stage. It seemed to us that the main reason why the problem had remained so long unsolved was that no one had been able to obtain any adequate practice. We figured that Lilienthal in five years of time had spent only about five hours in actual gliding through the air. The wonder was not that he had done so little, but that he had accomplished so much. It would not be considered at all safe for a bicycle rider to attempt to ride through a crowded city street after only five hours practice, spread out in bits of ten seconds each over a period of five years; yet Lilienthal with this brief practice was remarkably successful in meeting the fluctuations and eddies of wind gusts. We thought that if some method could be found by which it would be possible to practice by the hour instead of by the second, there would be hope of advancing the solution of a very difficult problem. It seemed feasible to do this by building a machine which would be sustained at a speed of 18 miles per hour, and then finding a locality where winds of this velocity were common. With these conditions, a rope attached to the machine to keep it from floating backward would answer very nearly the same purpose as a propeller driven by a motor, and it would be possible to practice by the hour, and without any serious danger, as it would not be necessary to rise far from the ground, and the machine would not have any forward motion at all. We found, according to the accepted tables of air pressures on curved surfaces that a machine spreading 200 square feet of wing surface would be sufficient for our purpose, and that places could easily be found along the Atlantic coast where winds of 16 to 25 miles were not at all uncommon. When the winds were low, it was our plan to glide from the tops of sand hills, and when they were sufficiently strong, to use a rope for our motor and fly over one spot. Our next work was to draw up the plans for a suitable machine. After much study we finally concluded that tails were a source of trouble rather than of assistance; and therefore we decided to dispense with them altogether. It seemed reasonable that if the body of the operator could be placed in a horizontal position instead of the upright, as in the machines of Lilienthal, Pilcher and Chanute, the wind resistance could be very materially reduced, since only one square foot instead of five would be exposed. As a full half horse power could be saved by this change, we arranged to try at least the horizontal position. Then the method of control used by Lilienthal, which consisted in shifting the body, did not seem quite as quick or effective as the case required; so, after long study, we contrived a system consisting of two large surfaces on the Chanute double deck plan, and a smaller surface placed a short distance in front of the main surfaces in such a position that the action of the wind upon it would counterbalance the effect of the travel of the center pressure on the main surfaces. Thus changes in the direction and velocity of the wind would have little disturbing effect, and the operator would be required to attend only to the steering of the machine, which was to be affected by curving the forward surface up or down. The lateral equilibrium and the steering to right or left was to be attained by a peculiar torsion of the main surfaces, which was equivalent to presenting one end of the wings at a greater angle than the other. In the main frame a few changes were also made in the details of construction and trussing employed by Mr. Chanute. The most important of these were; (1) the moving of the forward main cross-piece of the frame to the the extreme front edge; (2) the encasing in the cloth of all cross-pieces and ribs of the surfaces; (3) a re-arrangement of the wires used in trussing the two surfaces together, which rendered it possible to tighten all the wires by simply shortening two of them.

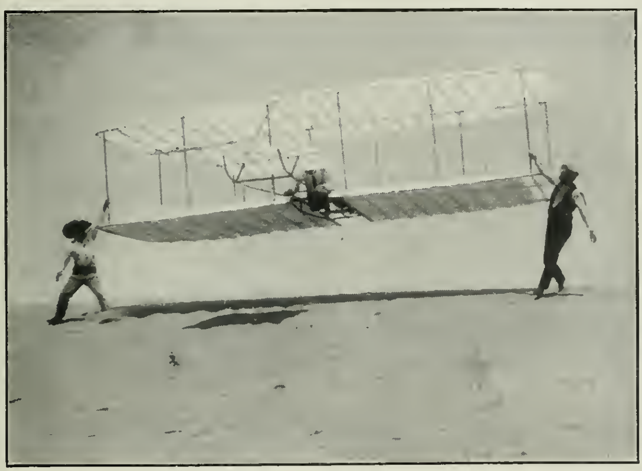
With these plans we proceeded in the summer of 1900 to Kitty Hawk, North Carolina, a little settlement located on the strip of land that separates Albemarle Sound from the Atlantic Ocean. Owing to the impossibility of obtaining suitable material for a 200 square foot machine, we were compelled to make it only 165 square feet in area, which according to the Lilienthal tables would be supported at an angle of three degrees in a wind of about 21 miles per hour. On the very day that the machine was completed the wind blew from 25 to 30 miles per hour, and we took it out for trial as a kite. We found that while it was supported with a man on it in a wind of about 25 miles, its angle was much nearer twenty degrees than three degrees. Even in gusts of 30 miles the angle of incidence did not get as low as three degrees, although the wind at this speed has more than twice the lifting power of a 21 mile wind. As winds of 30 miles per hour are not plentiful on clear days, it was at once evident that our plan of practicing by the hour, day after day, would have to be postponed. Our system of twisting the surfaces to regulate the lateral balance was tried and found to be much more effective than shifting the operator's body. On subsequent days, when the wind was too light to support the machine with a man on it, we tested it as a kite, working the rudders by cords reaching to the ground. The results were very satisfactory, yet we were well aware that this method of testing is never wholly convincing until the results are confirmed by actual gliding experience.



The 1900 Machine.

We then turned our attention to making a series of actual measurements of the lift and drift of the machine under various loads.

So far as we were aware this had never previously been done with with any full-size machine. The results obtained were most astonishing, for it appeared that the total horizontal pull of the machine, while sustaining a weight of 52 pounds, was only 8.5 lbs., which was less than had previously been estimated for head resistance of the framing alone. Making allowance for the weight carried, it appeared that the head resistance of the framing was but little more than 50 per cent of the amount which Mr. Chanute had estimated as the head resistance of the framing of his machine. On the other hand it appeared sadly deficient in lifting power as compared with the calculated lift of curved surfaces of its size. This deficiency we supposed might be due to one or more of the following causes: (1) That the depth of the curvature of our surfaces was insufficient, being only about 1 in 22, instead of 1 in 12. (2) That the cloth used in our wings was not sufficiently air tight. (3) That the Lilienthal tables might themselves be somewhat in error. We decided to arrange our machine for the following year so that the depth of curvature of its surfaces could be varied at will, and its covering air-proofed.



Starting a Flight.

Our attention was next turned to gliding, but no hill suitable for the purpose could be found near our camp at Kitty Hawk. This compelled us to take the machine to a point 4 miles south, where the Kill Devil sand hill rises from the flat sand to a height of more than 100 feet. Its main slope is toward the northeast, and has an inclination of 10 degrees. On the day of our arrival the wind blew about 25 miles an hour, and as we had had no experience at all in gliding, we deemed it unsafe to attempt to leave the ground. But on the day following, the wind having subsided to 14 miles per hour, we made about a dozen glides. It had been the original intention that the operator should run with the machine to obtain initial velocity, and assume the horizontal position only after the machine was in free flight. When it came time to land he was to resume the upright position and light on his feet, after the style of previous gliding experimenters. But on actual trial we found it much better to employ the help of two assistants in starting, which the peculiar form of our machine enabled us readily to do; and in landing we found that it was entirely practicable to land while still reclining in a horizontal position upon the machine. Although the landings were made while moving at speeds of more than 20 miles an hour, neither machine nor operator suffered any injury. The slope of the hill was 9.5 deg., or a drop of 1 foot in 6. We found that after attaining a speed of about 25 or 30 miles with reference to the wind, or 10 to 15 miles over the ground, the machine not only glided parallel to the slope of the hill, but greatly increased its speed, thus indicating its ability to glide on a somewhat less angle than 9.5 deg., when we should feel it safe to rise higher from the surface. The control of the machine proved even better than we had dared to expect, responding quickly to the slightest motion of the rudder. With these glides our experiments for the year 1900 closed. Although the hours and hours of practice we had hoped to obtain finally dwindled down to about two minutes, we were very much pleased with the general results of the trip, for setting out as we did, with almost revolutionary theories on many points, and an entirely untried form of machine, we considered it quite a point to be able to return without having our pet theories completely knocked in the head by the hard logic of experience, and our own brains dashed out in the bargain. Everything seemed to us to confirm the correctness of our original opinions, (1) that practice is the key to the secret of flying; (2) that it is practicable to assume the horizontal position, (3) that a smaller surface set at a negative angle in front of the main bearing surfaces, or wings, will largely counteract the effect of the fore and aft travel of the center of pressure, (4) that steering up and down can be attained with a rudder, without moving the position of the operator's body. (5) that twisting the wings so as to present their ends to the wind at different angles is a more prompt and efficient way of maintaining lateral equilibrium than shifting the body of the operator.

When the time came to design our new machine for 1901, we decided to make it exactly like the previous machine in theory and method of operation. But as the former machine was not able to support the weight of the operator when flown as a kite, except in very high winds and at very large angles of incidence, we decided to increase its lifting power. Accordingly, the curvature of the surfaces was increased to 1 in 12, to conform to the shape on which Lilienthal's table was based, and to be on the safe side, we decided also to increase the area of the machine from 165 square feet to 308 square feet, although so large a machine had never before been deemed controllable. The Lilienthal machine had an area of 151 square feet: that of Pilcher, 165 square feet; and the Chanute double decker, 134 square feet. As our system of control consisted in a manipulation of the surfaces themselves instead of shifting the operator's body, we hoped that the new machine would be controllable, notwithstanding its great size. According to calculations it would obtain support in a wind of 17 miles per hour with an angle of incidence of only 3 degrees.

A High Glide.

Our experience of the previous year having shown the necessity of a suitable building for housing the machine, we erected a cheap frame building, 16 feet wide, 25 feet long, and 7 feet high at the eaves. As our machine was 22 feet wide, 14 feet long (including the rudder) and about 6 feet high, it was not necessary to take the machine apart in any way in order to house it. Both ends of the building, except the gable parts, were made into doors which hinged above, so that when opened they formed an awning at each end, and left an entrance the full width of the building. We went into camp about the middle of July, and were soon joined by Mr. E. C. Huffaker, of Tennessee, an experienced aeronautical investigator in the employ of Mr. Chanute, by whom his services were kindly loaned, and by Dr. G. A. Spratt, of Pennsylvania, a young man who has made some valuable investigations of the properties of variously curved surfaces and the travel of the center of pressure thereon. Early in August, Mr. Chanute came down from Chicago to witness our experiments, and spent a week in camp with us. These gentlemen, with my brother and myself, formed our camping party, but in addition we had in many of our experiments the valuable assistance of Mr. W. J. Tate and Mr. Dan. Tate, of Kitty Hawk.

The machine was completed and tried for the first time on the 27th of July in a wind blowing about 13 miles an hour. The operator having taken a position where the center of pressure was supposed to be, an attempt at gliding was made; but the machine turned downward and landed after going only a few yards. This indicated that the center of gravity was too far in front of the center of pressure. In the second attempt the operator took a position several inches further back but the result was much the same. He kept moving further and further back with each trial, till finally he occupied a position nearly a foot back of that at which we had expected to find the center of pressure. The machine then sailed off and made an undulating flight of a little more than 300 feet. To the onlookers this flight seemed very successful, but to the operator it was known that the full power of the rudder had been required to keep the machine from either running into the ground or rising

A Low Glide.

so high as to lose all headway. In the 1900 machine one-fourth as much rudder action had been sufficient to give much better control. It was apparent that something was radically wrong, though we were for some time unable to locate the trouble. In one glide the machine rose higher and higher till it lost all headway. This was the position from which Lilienthal had always found difficulty to extricate himself, as his machine then, in spite of his greatest exertions, manifested a tendency to dive downward almost vertically and strike the ground head on with frightful velocity. In this case a warning cry from the ground caused the operator to turn the rudder to its full extent and also to move his body slightly forward. The machine then settled slowly to the ground, maintaining its horizontal position almost perfectly, and landed without any injury at all. This was very encouraging, as it showed that one of the very greatest dangers in machines with horizontal tails had been overcome by the use of a front rudder. Several glides later the same experience was repeated with the same result. In the latter case the machine had even commenced to move backward, but was nevertheless brought safely to the ground in a horizontal position. On the whole, this day's experiments were encouraging, for while the action of the rudder did not seem at all like that of our 1900 machine, yet we had escaped without difficulty from positions which had proved very dangerous to preceding experimenters, and after less than one minute's actual practice had made a glide of more than 300 feet, at an angle of descent of 10 degrees, and with a machine nearly twice as large as had previously been considered safe. The trouble with its control, which has been mentioned, we believed could be corrected when we should have located its cause. Several possible explanations occurred to us, but we finally concluded that the trouble was due to a reversal of the direction of the travel of the center pressure at small angles. In deeply curved surfaces the center of pressure at 90 degrees is near the center of the surface, but moves forward as the angle becomes less, till a certain point is reached, varying with the depth of curvature. After this point is passed, the center of pressure, instead of continuing to move forward, with the decreasing angle, turns and moves rapidly toward the rear. The phenomena are due to the fact that at small angles the wind strikes the forward part of the surface on the *upper* side instead of the lower, and thus this part altogether ceases to lift, instead of being the most effective part of all, as in the case of the plane. Lilienthal had called attention to the danger of using surfaces with a curvature as great as one in eight, on account of this action on the upper side; but he seems never to have investigated the curvature and angle at which the phenomena entirely ceases. My brother and I had never made any original investigation of the matter, but assumed that a curvature of one in twelve would be safe, as this was the curvature on which Lilienthal based his tables. However, to be on the safe side, instead of using the arc of a circle, we had made the curve of our machine very abrupt at the front, so as to expose the least possible area to this downward pressure. While the machine was building, Messrs. Huffaker and Spratt had suggested that we would find this reversal of the center of pressure. but we believed it sufficiently guarded against. Accordingly, we were not at first disposed to believe that this reversal actually existed in our machine, although it

FIG. 1.

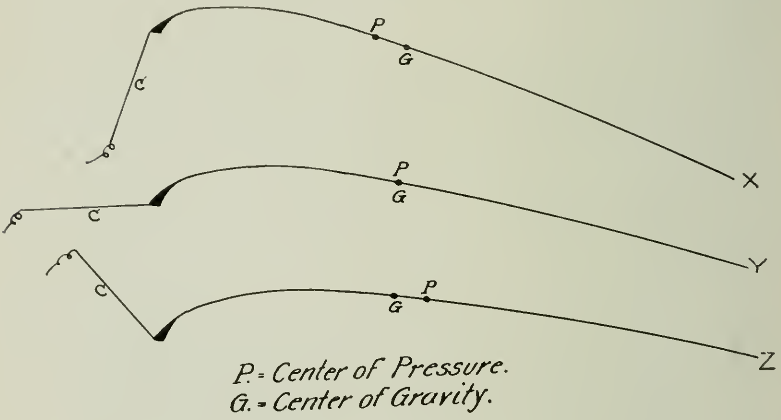
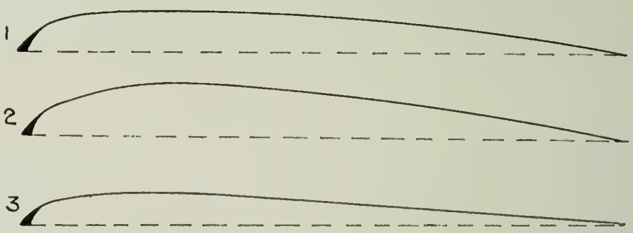


FIG. 2



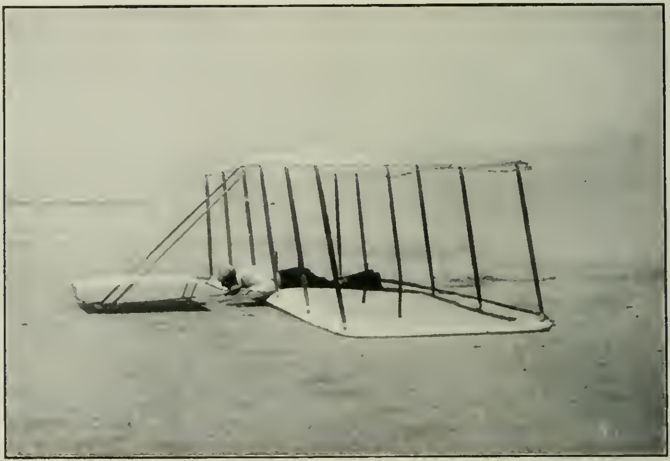
Diagrams of Pressures and Curves.

offered a perfect explanation of the action we had noticed in gliding. Our peculiar plan of control by forward surfaces, instead of tails, was based on the assumption that the center of pressure would continue to move farther and farther forward, as the angle of incidence became less, and it will be readily perceived that it would make quite a difference if the front surface instead of counteracting this assumed forward travel, should in reality be expediting an actual backward movement. For several days we were in a state of indecision, but were finally convinced by observing the following phenomena: (Figure 1) We had removed the upper surface from the machine and were flying it in a wind to see at what angles it would be supported in winds of different strengths. We noticed that in light winds it flew in the upper position shown in the figure, with a strong upward pull on the cord *c*. As the wind became stronger, the angle of incidence became less, and the surface flew in the position shown in the middle of the figure, with a slight horizontal pull. But when the wind became still stronger, it took the lower position shown in the figure, with a strong downward pull. It at once occurred to me that here was the answer to our problem, for it is evident that in the first case the center of pressure was in front of the center of gravity and thus pushed up the front edge; in the second case, they were in coincidence, and the surface in equilibrium; while in the third case the center of pressure had reached a point even behind the center of gravity, and there was therefore a downward pull on the cord. This point having been definitely settled, we proceeded to truss down the ribs of the whole machine, so as to reduce the depth of curvature. In Figure 2, line 1, shows the original curvature; line 2, the curvature when supporting the operator's weight; and line 3, the curvature after trussing.

On resuming our gliding, we found that the old conditions of the preceding year had returned; and after a few trials, made a glide of 366 feet and soon after one of 389 feet. The machine with its new curvature never failed to respond promptly to even small movements of the rudder. The operator could cause it to almost skim the ground, following the undulations of its surface, or he could cause it to sail out almost on a level with the starting point, and passing high above the foot of the hill, gradually settle down to the ground. The wind on this day was blowing 11 to 14 miles per hour. The next day, the conditions being favorable, the machine was again taken out for trial. This time the velocity of the wind was 18 to 22 miles per hour. At first we felt some doubt as to the safety of attempting free flight in so strong a wind, with a machine of over 300 square feet, and a practice of less than five minutes spent in actual flight. But after several preliminary experiments we decided to try a glide. The control of the machine seemed so good that we then felt no apprehension in sailing boldly forth. And thereafter we made glide after glide, sometimes following the ground closely, and sometimes sailing high in the air. Mr. Chanute had his camera with him, and took pictures of some of these glides, several of which are among those shown.

We made glides on subsequent days, whenever the conditions were favorable. The highest wind thus experimented in was a little over 12 meters per second—nearly 27 miles per hour.

It had been our intention when building the machine to do the larger part of the experimenting in the following manner: When the wind blew 17 miles an hour, or more, we would attach a rope to the machine and let it rise as a kite with the operator upon it. When it should reach a proper height the operator would cast off the rope and glide down to the ground just as from the top of a hill. In this way we would be saved the trouble of carrying the machine up hill after each glide, and could make at least 10 glides in the time required for 1 in the other way. But when we came to try it we found that a wind of 17 miles, as measured by Richard's anemometer, instead of sustaining the machine with its operator, a total weight of 240 lbs., at an angle of incidence of 3 degrees, in reality would not sustain the machine alone—100 pounds—at this angle. Its lifting capacity seemed scarcely one-third of the calculated amount. In order to make sure that this was not due to the porosity of the cloth, we constructed two small experimental surfaces of equal size, one of which was air-proofed and the other left in its natural state; but we could detect no difference in their lifting powers. For a time we were led to suspect that the lift of curved surfaces little exceeded that of planes of the same size, but further investigation and experiment led to the opinion that (1) the anemometer used by us over-recorded the true velocity of the wind by nearly 15 per cent; (2) that the well-known Smeaton



Landing.

coefficient of .005 V^2 for the wind pressure at 90 degrees is probably too great by at least 20 per cent.; (3) that Lilienthal's estimate that the pressure on a curved surface having an angle of incidence of 3 degrees equals .545 of the pressure at 90 degrees is too large, being nearly 50 per cent greater than very recent experiments of our own with a special pressure testing machine indicate; (4) that the superposition of the surfaces somewhat reduced the lift per square foot, as compared with a single surface of equal area.

In gliding experiments, however, the amount of lift is of less relative importance than the ratio of lift to drift, as this alone decides the angle of gliding descent. In a plane the pressure is always perpendicular to the surface, and the ratio of lift to drift is therefore the same as that of the cosine to the sine of the angle of incidence. But in curved surfaces a very remarkable situation is found. The pressure instead of being uniformly normal to the chord of the arc, is usually inclined considerably in front of the perpendicular. The result is that the lift is greater and the drift less than if the pressure were normal. Lilienthal was the first to discover this exceedingly important fact, which is fully set forth in his book, "Bird Flight the Basis of the Flying Art," but owing to some errors in the methods he used in making measurements, question was raised by other investigators not only as to the accuracy of his figures, but even as to the existence of any tangential force at all. Our experiments confirm the existence of this force, though our measurements differ considerably from those of Lilienthal. While at Kitty Hawk we spent much time in measuring the horizontal pressure on our unloaded machine at various angles of incidence. We found that at 13 degrees the horizontal pressure was about 23 lbs. This included not only the drift proper, or horizontal component of the pressure on the side of the surface, but also the head resistance of the framing as well. The weight of the machine at the time of this test was about 108 lbs. Now, if the pressure had been normal to the chord of the surface, the drift proper would have been to the lift (108 lbs.) as the sine of 13 degrees is to the cosine of 13 degrees, or $\frac{.22 \text{ x } 108}{.97}=24+$lbs.; but this slightly exceeds the total pull of 23 lbs. on our scales. Therefore, it is evident that the average pressure on the surface instead of being normal to the chord was so far inclined toward the front that all the head resistance of framing and wires used in the construction was more than overcome. In a wind of 14 miles per hour, resistance is by no means a negligible factor, so that tangential is evidently a force of considerable value. In a higher wind which sustained the machine at an angle of 10 degrees, the pull on the scales was 18 lbs. With the pressure normal to the chord, the drift proper would have been $\frac{.17 \times 98^*}{.98} = 17$ lbs., so that although the higher wind velocity must have caused an increase in the head resistance, the tangential force still came within one pound of overcoming it. After our return from Kitty Hawk we began a series of experiments to accurately determine the amount and direction of the pressure produced on curved surfaces when acted upon by winds at the various angles from zero to 90 degrees. These experiments are not yet concluded, but in general they support Lilienthal in the claim that the curves give pressures more favorable in amount and direction than planes; but we find marked differences in the exact values, especially at angles below 10 degrees. We were unable to obtain direct measurements of the horizontal pressures of the machine with the operator on board, but by comparing the distance traveled in gliding with the vertical fall, it was easily calculated that at a speed of 24 miles per hour the total horizontal resistances of our machine, when bearing the operator, amounted to 40 pounds, which is equivalent to about 2⅓ horse power. It must not be supposed, however, that a motor developing this power would be sufficient to drive a man-bearing machine. The extra weight of the motor would require either a larger machine, higher speed, or a greater angle of incidence, in order to support it, and therefore more power. It is probable, however, that an engine of 6 horse power, weighing 100 hundred pounds, would answer the purpose. Such an engine is entirely practicable. Indeed, working motors of one-half this weight per horse power (9 pounds per horse power) have been constructed by several different builders. Increasing the speed of our machine from 24 to 33 miles per hour reduced the total horizontal pressure from 40 to about 35 pounds. This was quite an advantage in gliding as it made it possible to sail about 15 per cent further with a given drop. However, it would be of little or no advantage in reducing the size of the motor in a power driven machine, because the lessened thrust would be counterbalanced by the increased speed per minute. Some years ago Prof. Langley called attention to the great economy of thrust which might be obtained by using very high speeds, and from this many were led to suppose that high speed was essential to success in a motor driven machine. But the economy to which Prof. Langley called attention was in foot pounds per mile of travel, not in foot pounds per minute. It is the foot pounds per minute that fixes the size of the motor. The probability is that the first flying machines will have a relatively low speed, perhaps not much exceeding 20 miles per hour, but the problem of increasing the speed will be much simpler in some respects than that of increasing the speed of a steamboat; for, whereas in the latter case the size of the engine must increase as the cube of the speed, in the flying machine, until extremely high speeds are reached, the capacity of the motor increases in less than simple ratio; and there is even a decrease in the fuel consumption per mile of travel. In other words to double the speed of a steamship (and the same is true of the balloon type of air ship) eight times the engine and boiler capacity would be required, and four times the fuel consumption per mile of travel; while a flying machine would require engines of less than double the size, and there would be an actual decrease in the fuel consumption per mile of travel. But looking at the matter conversely, the great disadvantage of the flying machine is apparent; for in the latter no flight at all is possible unless the proportion of horse power to flying capacity is very high; but on the other hand a steamship is a mechanical success if its ratio of horsepower to tonnage is insignificant. A flying machine that would fly at a speed of 50 miles an hour with engines of 1,000 horse power, would not be upheld by its wings at all at a speed of less than 25 miles an hour, and nothing less than 500 horse power could drive it at this speed. But a boat which could make 40 miles per hour with engines of 1,000 horse power, would still move 4 miles an hour even if the engines were reduced to 1 horse power. The problems of land and water travel were solved in the 19th century because it was possible to begin with small achievements and gradually work up to our present success. The flying problem was left over to the 20th century, because in this case the art must

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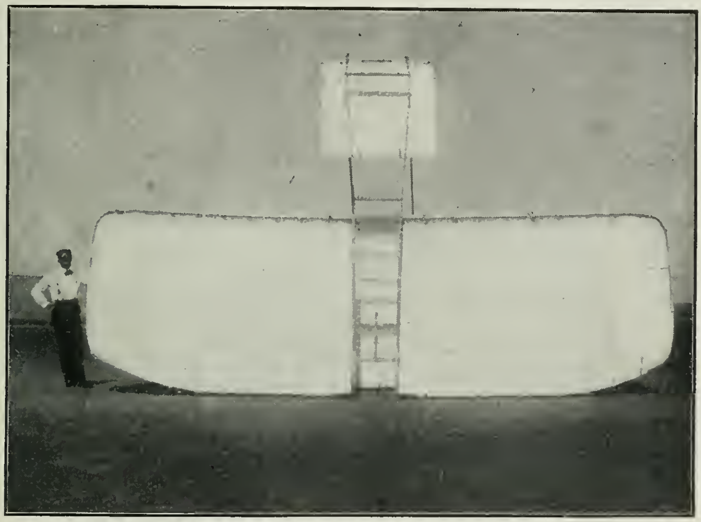
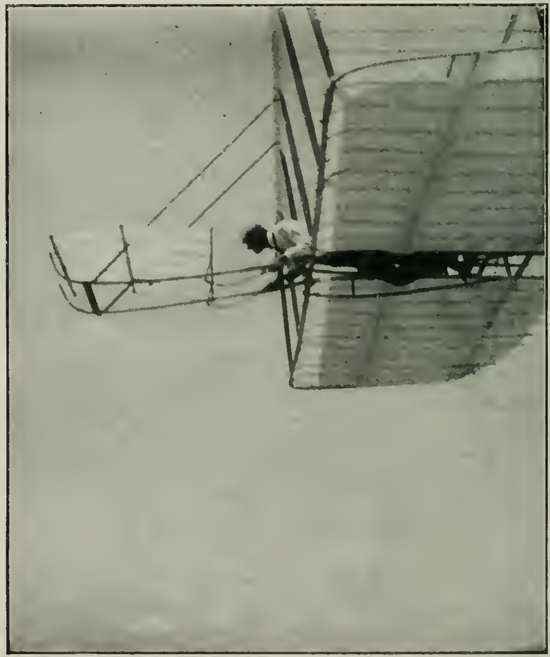
*The travel of the center of pressure made it necessary to put sand on the front rudder to bring the centers of gravity and pressure into coincidence, consequently the weight of the machine varied from 98 lbs. to 108 lbs. in the different tests.



A Bottom View.

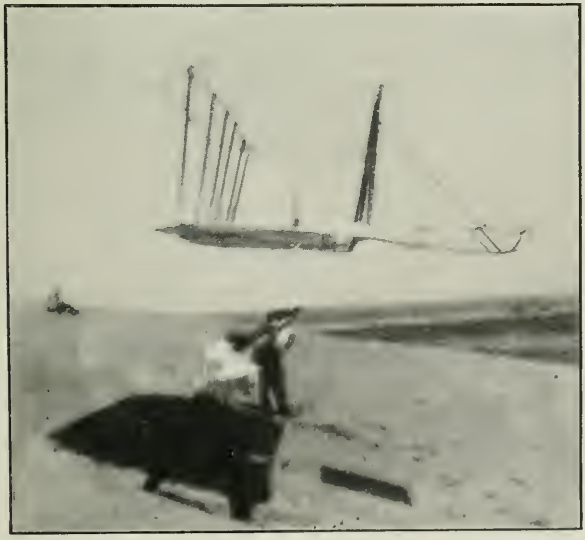
be highly developed before any flight of any considerable duration at all can be obtained.

However, there is another way of flying which requires no artificial motor, and many workers believe that success will first come by this road. I refer to the soaring flight, by which the machine is permanently sustained in the air by the same means that are employed by soaring birds. They spread their wings to the wind, and sail by the hour, with no perceptible exertion beyond that required to balance and steer themselves. What sustains them is not definitely known, though it is almost certain that it is a rising current of air. But whether it be a rising current or something else, it is as well able to support a flying machine as a bird, if man once learns the art of utilizing it. In gliding experiments it has long been known that the rate of vertical descent is very much retarded and the duration of the flight greatly prolonged, if a strong wind blows *up* the face of the hill parallel to its surface. Our machine, when gliding in still air, has a rate of vertical descent of nearly 6 feet per second, while in a wind blowing 26 miles per hour up a steep hill, we made glides in which the rate of descent was less than 2 feet per second. And during the larger part of this time, while the machine remained



Soaring.

exactly in the rising current, *there was no descent at all, but even a slight rise.* If the operator had had sufficient skill to keep himself from passing beyond the rising current, he would have been sustained indefinitely at a higher point than that from which he started. The illustration shows one of these very slow glides at a time when the machine was practically at a standstill. The failure to advance more rapidly caused the photographer some trouble in aiming, as you will perceive. In looking at this picture you will readily understand that the excitement of gliding experiments does not entirely cease with the breaking up of camp. In the photographic dark room at home we pass moments of as thrilling interest as any in the field, when the image begins to appear on the plate and it is yet an open question whether we have a picture of a flying machine, or merely a patch of open sky. These slow glides in rising currents probably hold out greater hope of extensive practice than any other method within man's reach, but they have the disadvantage of requiring rather strong winds or very large supporting surfaces. However, when gliding operators have attained greater skill, they can, with comparative safety, maintain themselves in the air for hours at a time in this way, and thus by constant practice so increase their knowledge and skill that they can rise into the higher air and search out the currents which enable the soaring birds to transport themselves to any desired point by first rising in a circle and then sailing off at a descending angle. This illustration



Kite Soaring.

shows the machine, alone, flying in a wind of 35 miles per hour on the face of a steep hill, 100 feet high. It will be seen that the machine not only pulls upward, but also pulls forward in the direction from which the wind blows, thus overcoming both gravity and the speed of the wind. We tried the same experiment with a man on it, but found danger that the forward pull would become so strong that the men holding the ropes would be dragged from their insecure foothold on the slope of the hill. So this form of experimenting was discontinued after four or five minutes' trial.

In looking over our experiments of the past two years, with models and full size machines, the following points stand out with clearness:

1. That the lifting power of a large machine, held stationary in a wind at a small distance from the earth, is much less than the Lilienthal table and our own laboratory experiments would lead us to expect. When the machine is moved through the air, as in gliding, the discrepancy seems much less marked.

2. That the ratio of drift to lift in well shaped surfaces is less at angles of incidence of 5 deg. to 12 deg. than at an angle of 3 deg.

3. That in arched surfaces the center of pressure at 90 deg. is near the center of the surface, but moves slowly forward as the angle becomes less, till a critical angle varying with the shape and depth of the curve is reached, after which it moves rapidly toward the rear till the angle of no lift is found.

4. That with similar conditions, large surfaces may be controlled with not much greater difficulty than small ones, if the control is effected by manipulation of the surfaces themselves, rather than by a movement of the body of the operator.

5. That the head resistances of the framing can be brought to a point much below that usually estimated as necessary.

6. That tails, both vertical and horizontal, may with safety be eliminated in gliding and other flying experiments.

7. That a horizontal position of the operator's body may be assumed without excessive danger, and thus the head resistance reduced to about one-fifth that of the upright position.

8. That a pair of superposed, or tandem surfaces, has less lift in proportion to drift than either surface separately, even after making allowance for weight and head resistance of the connections.

CXXXIII.

WASHING OF BITUMINOUS COALS BY THE LUHRIG PROCESS.

By Mr. J. V. Schaefer, of the Link-Belt Machinery Company.

Presented October 2, 1901.

The importance of the subject which I am to present to you to-night, together with the high standing of this Society among the engineers of this country, really deserves more careful preparation than I have been able to give it, but it is such a pleasure to do business for the Link-Belt Machinery Company that I work overtime at it. You are all busy men in these prosperous times and fully appreciate the difficulty one has in finding time to put on paper what he may wish to say on an engineering subject.

My business, as you will discover before I get through, has a great deal to do with sprocket wheels. I have been told that I have my business on my mind constantly. However this may be, I trust I may be able to give you an off-hand talk on this subject, which will be sufficiently clear and connected as not to jar unpleasantly on your engineering sensibilities.

Before taking up the discussion of the Luhrig process of washing coal, in particular, I wish to spend a little time in discussing the matter of coal washing in general, a subject with which engineers in this country are as yet unfamiliar.

The washing of coal, like the washing of ore, is for the purpose of separating from each other, pieces of matter having different specific gravities. In the washing of ore, the ore is the heaviest and sinks to the bottom and the refuse rises and is washed away, while in the washing of coal the contrary is true—the refuse matter is heaviest and sinks to the bottom, while the coal is floated away.

The foreign matters or impurities which it is essential to wash out of the coal are slate, sulphur, bone coal and fire clay. The specific gravity of coal is about 1.27 to 1.30. Matter which is materially heavier than this can be separated from the coal by a process of washing.

Slate is as heavy as 1.50 or 2.00 even, so it is very readily removed from coal.

Sulphur occurs in several different forms, mainly as iron pyrites. As iron pyrites it may occur as solid, dense masses. These are very heavy and easily removed. It may occur also in thin flakes that may be disseminated throughout the entire mass in small particles. When it exists in that form it is somewhat difficult to remove, for the reason that there may not be enough weight to make the lump sink. In that case it cannot be removed. These thin flakes of sulphur I have also known to float away on the surface of the water, although they may have been heavy enough to sink. They may take a cup shape like a piece of tin with the edges bent, and are sometimes difficult to remove.

Another form of sulphur in coal is in the form of sulphate of lime and magnesia. This usually occurs in thin white flakes that may be disseminated—in thin sheets like paper—through the coal. While sulphur in this form is in itself heavy enough to sink, it usually occurs—as you will see it in the northern Illinois coals—throughout a mass in such small parts that it is not sufficient to materially affect the weight of the total mass.

Another form is organic sulphur—the worst of all. It cannot be detected by any physical inspection and it cannot be removed by any physical process.

Bone coal is an impure form of coal. It varies all the way from a slatey coal to a coaly slate. It is very difficult to determine just where to draw the line between what is refuse and what is coal in the case of bone coals. There are coals in which this is a very serious matter—coals in which the bone is disseminated throughout the entire mass, or in thin seams so closely interstratified that if you attempt to remove the bone you would have very little coal left. Bone coal frequently gives very great trouble in washing.

The difficulty with fire clay is its solubility (To speak correctly it does not really dissolve, but it emulsifies.) It is apt to dissolve, forming a sticky mud. This fills up the holes in the screens, settles to the bottom of the tanks and makes trouble generally. So any great quantity of fire clay is apt to make trouble with the machinery.

All of these impurities show themselves in the ashes when the coal is burned. The ordinary coal screenings, as they come to Chicago from the various coal fields tributary to this market, contain as much as 10 to 25 per cent of ash. These coals can usually be reduced, by a process of washing, to 5, 10 or 12 per cent of ash. These same coals contain all the way from part of 1 per cent to 3 and 4 and possibly 5 per cent of sulphur. This sulphur can also be partially removed from the coal. In a fuel coal, if the sulphur does not exceed 1½ per cent, it does not greatly affect the value. If it runs as high as 3 or 4 per cent, it is a very serious matter. The sulphur existing as iron pyrites, introduces iron into the ash, which melts with it into a clinker that becomes very hard.

In coking coal, the matter of sulphur is of vital importance, for the reason that coke used for melting iron may not exceed 1 per cent. of sulphur, and coke that goes above that is not used in the cupola or blast furnace. If a coking coal contains sulphur it is of vital importance that it be washed out if it can be done.

So far I have mentioned these impurities only in their separate state. What is to be done with a piece of coal having refuse matter in it? — coal containing a piece of slate or sulphur. What becomes of this piece? If there is enough of the foreign matter attached to the piece of coal to make it heavy enough to sink, it will be rejected; if not, it will go with the coal. Either one of these cases is bad. In the first case a quantity of coal will be lost in the refuse. In the second case we shall be leaving in the coal the very matter which we are trying to get out. One way is to crush the coal and thus free the foreign matter, but there are difficulties in doing that. You all know that in the case of a fuel coal the selling value depreciates very materially with the size, so it would not do to crush all the coal. In the case of coking coal it is of no advantage to crush it. In the first place, it is much more difficult to wash a fine coal than a coarse coal; the process is much more difficult and much slower. In the second place, a great deal of the impurities, when crushed, will be reduced to fine slime and cannot be removed. Take a piece of nut coal the size of a goose egg. There is a certain quantity of foreign matter in that piece. If that entire piece can be rejected, then all the impurity contained in that coal will be kept once and forever out of the coal. If you crush it, you are going to free a certain quantity of that impurity which you will never get out. The only thing to be done, as is done in the Luhrig process, is to reject every piece that has a suspicion of having foreign matter in it, and then to crush and re-treat that primarily rejected product and recover all parts that are of value and use them as an inferior grade of coal. So much for the impurities of the coal.

The appliances that are used for washing coal may be grouped into four general classes:

1st. The Trough Washer.
2nd. The Campbell Bumping Table.
3rd. The Robinson, or Inverted Cone Washer.
4th. The Jig Washer.

The Trough Washer consists of an open end trough set on an incline, with cross riffles in the bottom. The coal is sluiced into the upper end and the water flows out of the lower end. A conveyor with flights running up stream carries the clean coal out at the upper end while the refuse gathers on the riffles. At regular intervals the stream of coal is interrupted, the refuse is cleared off of the cross riffles at the bottom, and then the process is begun over again. This is very crude and hardly deserves to be called a washing process.

The second form is the Campbell Bumping Table. This, as I have seen it made, is a shallow wooden trough 30 inches by 6 feet or 8 feet long, open at the ends. The depth is 8 inches and may be 6 inches or 5 inches at the ends. It is hung in a slightly inclined position, one end slightly higher than the other, and by means of a cam motion it is thrown, at regular intervals of time, against a bumping post at the upper end. The bottom of the table is formed by a piece of galvanized iron. A couple of inches up from the bottom is a false bottom, with riffles, pointing up hill. The coal is sluiced on by means of water, and as the bumping table is thrown violently against the bumping post, the refuse is thrown up hill, off the upper end, while the coal floats off the lower end with the water.

The third form of washer is the inverted cone or Robinson washer. This consists of a conical steel tank, set vertically. There is a vertical shaft acting through the center. The shaft carries a pair of cross arms at the top, which carry vertical stirring arms. Water is forced in at the bottom and flows out through an opening in the upper edge of the cone. Coal is fed in near the center at the top. The refuse matter gradually settles to the bottom and is removed at regular intervals by opening valves or slides, while the clean coal flows out at the top with the water.

Both of these two forms of washing device fall very far short of accomplishing perfect results. The Campbell table is too delicate. The entire body of coal under operation at one time does not exceed about three inches in thickness. The slightest variation in the relative quantities of coal and water affects the operation. The Robinson washer is quite effective on the coarser sizes, but fails on the finer sizes. Both have been used to some extent for washing coals for fuel, but where requiremeuts have been severe and regard has been had for keeping the coal out of the refuse and making the coal as clean as it is possible to do, each have failed, as in Pennsylvania and Nova Scotia. The only device which seems to lend itself perfectly to the separation of coal, as it has been fully demonstrated to lend itself to the separation of ores, is a jig.

A jig is made in a variety of ways and jigs have been designed by a number of people. The jigs usually take the name of the inventor, and there are jigs in this country in quite a variety. Some are good, some bad and some indifferent. It would not be worth your while to attempt to describe all of these. I will simply describe the Luhrig. The operation of these jigs differs in detail. The foundation principle at the bottom of all is the same. The Luhrig jig consists of a rectangular box. (See Fig. I.) If the capacity demands a number of jigs, this box is simply made long enough to be divided by partitions into as many jigs as are required.

Each jig is divided by a partition from the top about half way down, dividing the jig box into two compartments—rear and front. In the rear compartment a plunger plays up and down, and water is forced in from beneath the plunger. The front compartment is closed near the bottom by means of a screen plate. Coal is fed in immediately in front of the partition. The water is caused to take a pulsating motion by means of the plunger, and the water forces its way up and down and gradually works forward to the point of issue and effects a separation between the coal and the refuse, so that by the time they have worked forward to the front end of the jig box the refuse is safely in the bottom and the coal at the top. Near the center at the front is an opening immediately above the screen plate and through that opening the refuse works its way. The opening is guarded by means of a slide having a hole in it, so that the location of this opening, as well as its size, may be regulated by the operator. The coal issues in two openings on either side of the slate valve. As the refuse works its way out it drops into a compartment in front of the jig, is pulled to to the end of this compartment with a screw conveyor, and an elevator lifts the refuse out of the water and disposes of it. You will notice that the refuse lies at the bottom and prevents the screen plate from allowing any of the fine coal that may happen to be small enough, to work its way back.

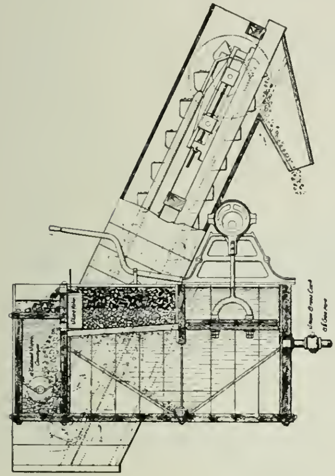


Fig. I.—Nut Coal Jig.

Let us consider the operation of the jig. When we first put the coal into the jig there is no refuse on the bottom. Some of the coal will go directly through the holes at the bottom and be wasted, but after the operation has continued for half an hour or so, there will be a layer of refuse at the bottom which will prevent the coal from being wasted. Now if the coal put into that jig is fine—say below ½-inch—then the refuse contained in that coal is not sufficiently large to make an effective layer of refuse on the plate. It would form too dense a mass. The interstices would not be large enough to allow water and refuse to work through. In order to overcome that point Mr. Luhrig uses a jig much the same shape, the design being a little different, but the principle exactly the same, but he places on top of this screen plate a layer of feldspar crushed to uniform size. This forms a permanent artificial layer of refuse, and as the coal rises with the water, the refuse works its way down through the interstices of the feldspar and gets down to the bottom of the jig. That is the feldspar jig as it is used in Luhrig plants. (See Fig II).

Right at this point I want to warn you against the error which is quite common of assuming that a successful jig, or bumping table, or inverted cone assures the success of the washing plant. Nothing, I assure you, could be further from the truth. The machine which actually does the washing is a very small part of the entire plant. Many other parts of the plant are essential to the success of the plant. Let me illustrate:

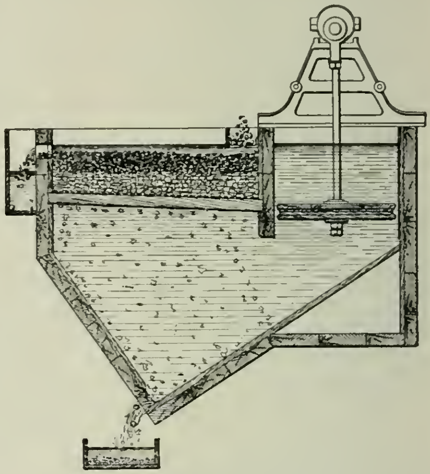


Fig. II.—Fine Coal Jig.

I will assume that I have plenty of steam pressure and wish to use that steam pressure to drive a mill. I go to a machine shop and say to the proprietor that I have plenty of pressure and need some kind of a machine that will change that static pressure into motion, and ask what he will charge for a machine to convert my steam pressure into motion. He tells me $300. Then I go to another machine shop and state the same case. The proprietor says he would like to know a little more about the kind of motion I propose to use, etc. He then states that, without knowing any more about it, he thinks I should have a complete steam engine which he can make for something like $1,200. I buy the $300 machine and when I unload it from the car I find I have received a well designed and well executed steam cylinder. But I do not see how I can use that. I call in the manufacturer and tell him I do not see how I can drive my machinery with that thing. He tells me that is just what I asked for and that that is a machine for converting my pressure into motion. I tell him that I seem to need something else. He replies, "Of course, I supposed you knew that. In addition you will have to have a shaft, fly wheel, etc., and when you have those pieces all put together and a belt run from your wheel to the line shaft you can then run your mill." I ask what will be the cost. He replies, that will depend on how much money I wish to put into my plant; that I can possibly pick up a second-hand fly wheel somewhere; that the pillow blocks can be gotten from the Link-Belt

Machinery Company at moderate cost, and other parts obtained in various places. He also says that his responsibility ends in furnishing the machine for converting pressure into motion, and that it is a good machine.

Gentlemen, this Illustration is not overdrawn and is a parallel case. Time and time again men have come to me and said: "We understand you make the Luhrig coal washer and that it is very expensive. Now, we can buy a Robinson washer for so much money and a Campbell bumping table for so much money, but we understand the Luhrig washer costs thousands of dollars. Now we want the best if we can afford to buy it. At what price can you furnish a Luhrig washer having a capacity of 500 tons a day?"

If I were to answer that question I would give the answer which my first machine shop man gave to my hypothetical question, but, gentlemen, I think much of my integrity as an engineer, and I will not purposely mislead anyone who comes to me honestly with an honest question, so I do not answer the question in the way it was asked, but I say: "The only thing I can answer is this—that the Luhrig washer will not cost you any more money than any other kind of washer that is equally well built and will accomplish the same results. Let me repeat, that *the Luhrig washer will not cost any more than any other kind of washer that is equally well built and will accomplish the same results*." I also say to him: "If you will send me a barrel of your coal and the plat of the ground on which the plant is to be built,—or, better still, if you will go with me to the mines—I will exomine the coal and see if it can be successfully washed; then I will draw up plans and an estimate on such a plant as will do your work." This is the only answer to make. If you wish to buy an engine or dynamo you can go into the market and, without the advice of a consulting engineer, buy it, and not go very far wrong; but if you had a case at law, or if you were sick, or if you were going to build a sky-scraper like the one we are in, you would very likely consult the best lawyer, the best physician, or the best architect that you could afford to employ. In coal washing you would need to get the advice of an engineer who is well posted in that kind of work. The engineer must know something about coal; must know something about how to treat coal, and must be able to design a plant, regardless of what other plants may be doing, that will meet your particular requirements; for *the mere imitation of previously executed designs, be they ever so successful, when applied to new coal, new conditions, etc., is certain to prove disappointing.*

Now, what is the Luhrig process? The Luhrig process is simply this: It is the result of the life-long labors of Mr. Karl Luhrig among the dirty coals of Germany, added to which is the experience of engineers working with Mr. Luhrig, in treating the dirty coals of Scotland, England, and, in fact, the world around. Mr. Luhrig was an engineer. He was familiar with the processes of washing ores. He applied these processes to washing coals. He experimented with one thing and another. He built many plants, and after a great deal of experimenting he finally found that certain things were essential to the successful operation of a coal washing plant. These things have been included in the Luhrig system. He found that in order to thoroughly separate coals it was necessary to do with coals what has for centuries been known with regard to ore—first to separate into sizes and then treat these sizes separately by jigs specially designed for those sizes. He found, further, that there was only one device that would thoroughly wash fine coal by itself. That is the feldspar jig. He found that the method of hydraulically grading ores was applicable to the grading of coal, and included the Luhrig grading box in the Luhrig process. He found that the elevators would have to be built in a particular way, as the elevators as ordinarily built for other purposes will not answer for coal washing purposes. He found that the handling of water in the coal washer was a very serious problem. The amount of water that is usually required is very great. If the water has to be wasted, nothing but a running stream will supply it, and when it is used and turned loose it will make a great deal of trouble by overflowing the lands on a lower level and depositing a layer of fine black sediment on them. But worse than all that, this very black sediment that is making you trouble is pure coal and you are losing it. It will surprise you to hear me make the statement that the water that has been clarified in the Luhrig Sludge Recovery has been known to carry as much as three pounds of coal per gallon. This fine coal—almost as fine as powder—is good fuel. In coking coal this fine coal is usually the very best coal you have in the mine. It is the pure coal. So you cannot afford to lose this coal. This was the problem solved by Mr. Luhrig when he designed the Luhrig Sludge Recovery, as now used.

I have with me to-night lantern slides showing two designs of Luhrig washers. One design is for handling 50 tons per hour; the other for handling 100 tons per hour. The lantern slides from the design for handling 50 tons were made by tracing off the designs for a plant that was actually built a little over a year ago. Some modifications of this design have been used in a number of plants, so that these designs are not imaginary; they are of plants that are in satisfactory operation. The plant of 100 tons per hour was put in operation a month ago; it was designed and built for the Buckeye Coal & Railway Company of Nelsonville, Ohio. This plant has been running since it was put in, day and night constantly. These designs are of plants in actual operation.

I will try, briefly, to follow the coal and refuse through the plant from the point where the coal is received to the point where the coal is delivered into the cars and the refuse is discarded, and in that way I believe you will get more quickly and more thoroughly an idea of the latest and best designs of Luhrig plants as they exist in this country today.

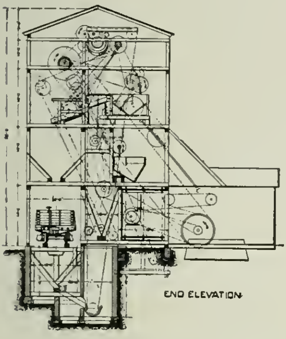


Fig. III.—Fifty Ton Plant.

This is an end view (see Fig. III) of a 50-ton per hour plant for washing coal for fuel purposes as it is used in Illinois by Donk Bros. Coal & Coke Company, of Collinsville, Illinois, and by the New Ohio Washed Coal Company, Carterville, Illinois.

The coal is received on the track shown and is dumped into the pit under the track, if they have dump cars; if they do not have dump cars then an unloading machine is put over this track. In either case the coal comes into this pit. From there it is delivered into an elevator which lifts the coal once and for all into the top of the building. At the top of the building is a triple jacketed screen which divides the coal primarily into two classes; first, the nut coals Nos. 1, 2 and 3; second, the fine coal passing through the ¾-inch holes. The nut coals from the three ends of the triple jacketed screen are dropped into their respective jigs. When washed, the clean nut coal is sluiced out of the front of the jig, with the stream of water which floats it there, and falls upon the bumping screen, which is simply a wooden frame carrying a screen plate on the bottom. The coal is sluiced on to the bumping screen at the upper end with the stream of water. That gradually shakes the coal off the lower end and gives the water plenty of time to escape. The coal at this point falls directly into the shipping bins over the track. The refuse (from the nut coal) in the mean time has been taken out of the water by the elevator. The fine coal, in the mean time, passing through the outer jacket, is met by all the

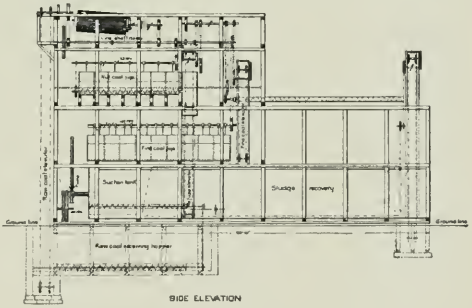


Fig. IV.—Fifty Ton Plant.

water which has been gathered by the sluice box under the bumping screen. The water sluices the coal into the grading box, which is a V-shaped tank. The water flows in at one end in a horizontal direction. As the water flows across and mingles with the body of water in the tank, the velocity diminishes, so that in this grading box the coal simply settles gradually; the largest first and the finest later on. Each fine coal jig gets a different size of coal. The eccentrics are adjustable for their stroke to suit the size of coal to be treated. The fine coals, although they are separated into sizes hydraulically in washing, are all mixed again and are sluiced into the fine coal elevator. The water which has been drained from the coal by the elevator which lifts the fine coal into its bin, is all gathered together in the sludge tank. The refuse matter, which has been discharged from the bottom of the nut coal jigs and from the bottom of the fine coal jigs, with the water which is used to sluice it out of these jigs, goes into the refuse recovery. This is a V-shaped tank with a screw conveyor in the bottom and an elevator in one end. The entire plant is driven from the engine in the engine house at one side of the building by means of rope transmission. The water in the sludge recovery tank is usually eight feet deep.

The sludge tank occupies nearly the entire length of the building, 75 feet long. The tank is made water tight, with a conveyor from end to end, and at one end a pit is built on to it. In that pit an elevator is placed. The water which has been used throughout the entire plant is all sluiced together directly into this sludge elevator. Such portion of the coal as goes through the perforations of the sludge elevator buckets escapes into the tank. The stream of water flows very slowly in this tank, so the velocity of the water is very low. As the fine coal settles to the bottom the conveyor, which is a triple line of chain-carrying scrapers moving very slowly, scrapes the sludge to the end, drops it into the elevator, and the elevator takes it out. The suction of the pump is at the other end. All the coal which will settle at all will be deposited and taken out, and the water taken on through the plant and used over and over. The only water that is lost is that which goes away with the wet coal. The only additional water that is needed is supplied as a spray over the bumping screens. A stream of clear, fresh water is directed on the coal just before it falls into the bins, and all the dirty water is rinsed off.

Figs. V and VI are views of the plant having a capacity of 100 tons per hour, which has been recently started by the Buckeye Coal & Railway Company. The description of this plant is almost identical with that of the plant I have just given. It has some special features. The capacity of the plant was such that we had to double

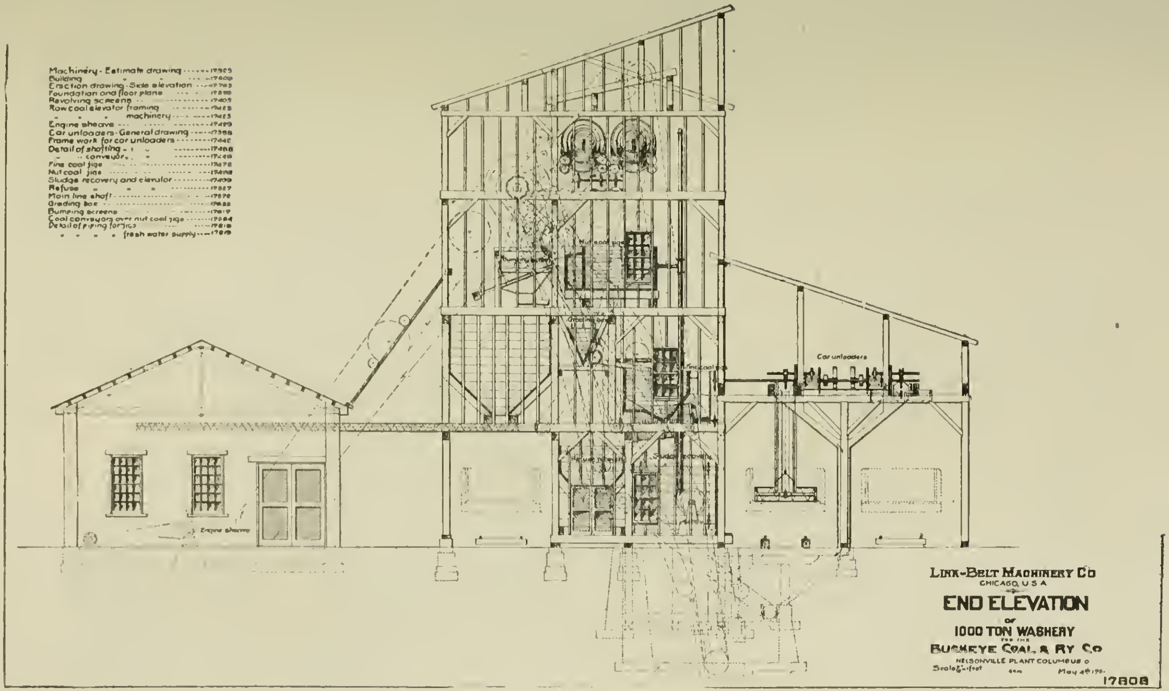


FIG. V.—100-Ton Plant.

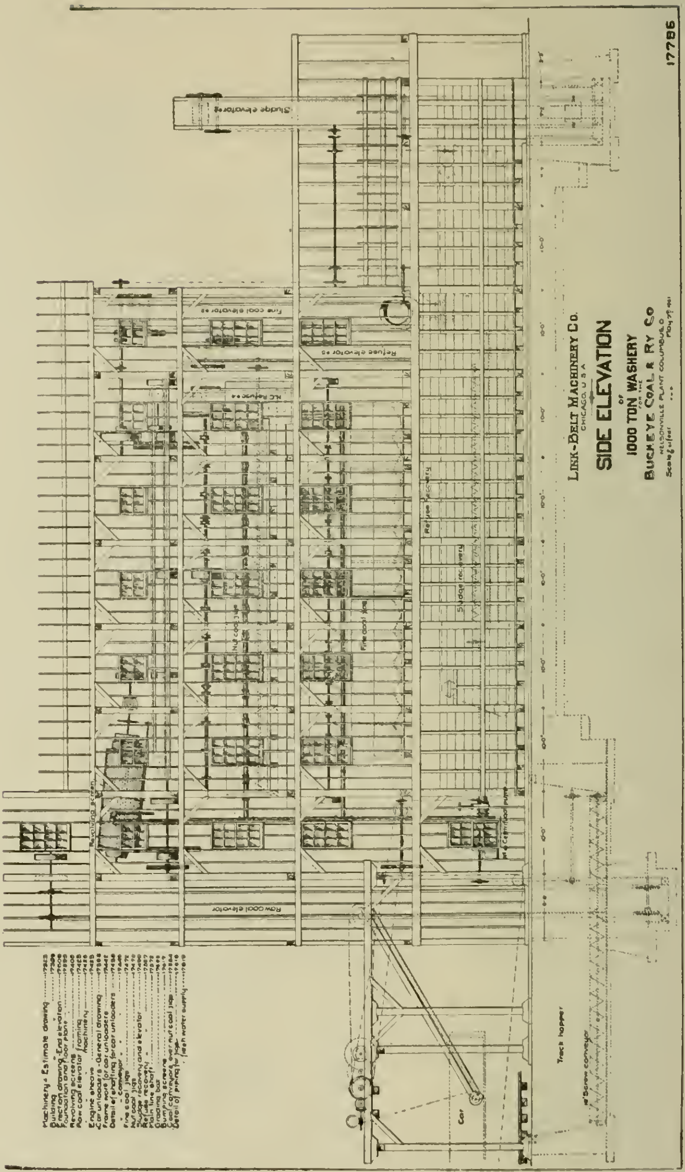


FIG. VI.—100-Ton Plant.

the screening capacity, and we have a pair of triple jacketed screens. Every pound of coal has to be unloaded at the plant. An elevator lifts it to the top and it goes on down through the process. The power house in this case was made separate from the rest of the plant. The fuel for this plant is taken from the fine coal bins at one end by means of a conveyor. Fuel in most of these plants is taken from the very fine coal. The No. 5 is what they intend to burn. It is the coal that goes through the ¼-inch holes that they use for fuel. You will see that this is almost a duplicate of the other plant. In this case a little different arrangement is made of the fine coal. The fine coal is sluiced to a draining screen before going to the fine coal elevator, and so another size of coal is made. The fine is what escapes through the openings in that screen, and the other size is what passes from the end of that screen.

Before going any further I wish to inquire if any one desires to ask any questions.

Mr. W. R. Roberts—Do you mix the different sizes after they have been once separated, or are they marketed in different sizes after separating?

Mr Schaefer—They are marketed in different sizes. People are used to getting mixed sizes and sometimes ask for them, but they are not desirable nor economical. To get the most value out of a fuel it is better to have it uniform in size. If you look into a furnace where coal is burning, when a uniform size is used, you will see that it lies in a uniform bed, and you get a better draft and more complete combustion. A fine coal alone is better than a fine coal mixed with coarse coal.

Most of the Luhrig washed coal that is sold is in five sizes:

Size No. 1 goes through a 2½-inch hole and over a 1¾-inch hole.
" " 2 " " " 1¾ " " " " " 1 " "
" " 3 " " " 1 " " " " " ¾ " "
" " 4 " " " ¾ " " " " " 3/16 " "
" " 5 " " " 3/16-inch hole.

The latter is the fine coal.

Mr. Roberts—My question is, taking any particular grade or kind of coal, what is the relative efficiency of that for fuel purposes after the washing and before?

Mr Schaefer—I will answer that question by the following list of Luhrig plants, showing analyses of coals treated in these plants both before and after washing:

	Before Washing			After Washing		
	Ash.	Sulphur	Fixed Carbon	Ash.	Sulphur	Fixed Carbon
Belt Mountain, Montana	18.74	3.34	43.72	5.56	2.40	48.39
Wellington Colliery Co., Vancouver Island (new coal)	35.00		38.00	8.90		56.90
Alexandria Coal Co., Crabtree, Pa.	10.60	1.30		6.21	0.61	
DeSoto, Ill.	18.00		44.00	4.20		57.00
Northwestern Improvement Co., Roslyn, Wash.	16.30	0.57	45.90	9.70	0.40	47.86
Luhrig Coal Co., Zaleski, O.	15.80	1.90		8.00	0.87	50.90
Rocky Fork Coal Co , Red Lodge, Mont.	25.30		37.80	8.50		47.20
Buckeye Coal & Ry. Co., Nelsonville, O.	13.77	1.05	49.04	4.30	0.89	54.82
New Ohio Washed Coal Co., Carterville, Ill.	9.48	0.78	55.00	4.85	0.69	63.00

These, I think, will answer Mr. Roberts' question.

Mr. Roberts—That suggests another question, viz.: whether this coal-washing applies to all kinds of coals, or bituminous coal only, or some particular grade of bituminous?

Mr. Schaefer—Nothing I have said tonight applies to anthracite coal; only to bituminous.

Mr. Rice—Have you any figures from Donk Bros. Coal & Coke Company?

Mr. Schaefer—No analyses.

Mr. Rice—I have heard that the plant is operating very successfully.

Mr. Schaefer—I have no analyses yet, but have been hoping every day to get them.

The following is a list of the Luhrig coal washing plants in operation in this country at the present time. The first plant built in this country was built in 1894:

1.	St. Louis & Big Muddy Coal Co., Carterville, Ill.	600 tons fuel.	1894
2.	Anaconda Copper Mining Co., Belt, Montana	400 tons coke,	1895
3.	R. Dunsmuir & Sons, Vancouver Island, B. C.	600 tons coke,	1896
4.	St. Louis & Big Muddy Coal Co., DeSoto, Ill.	300 tons fuel,	1896
5.	Luhrig Coal Company, Zaleski, Ohio	400 tons fuel,	1897
6.	Alexandria Coal Co., Greensburg, Pa.	600 tons coke,	1897
7.	Rochester & Pittsburgh Coal & Iron Co., Punxsutawney, Pa	800 tons coke,	1898
8.	Donohue Coke Co., Greensburg, Pa.	600 tons coke,	1899
9.	Donk Bros. Coal & Coke Co., Collinsville, Ill.	500 tons fuel,	1900
10.	Buckeye Coal & Ry. Co., Nelsonville, Ohio	2000 tons fuel,	1901
11.	New Ohio Washed Coal Co., Carterville, Ill.	600 tons fuel,	1901
12.	Rocky Fork Coal Co., Red Lodge, Mont.	500 tons fuel,	1901

In conclusion I will invite all those who are interested to look at these samples of coal, washed by the Luhrig process, taken from cars of washed coal from the washery of the New Ohio Washed Coal Co.

Mr. Finley—I would like to ask if any Illinois coals are being coked? Can they be coked?

Mr. Schaefer—I hardly know. They may possibly be doing it at Murphysboro. I do not know of any other plant.

Mr. Rice—I believe the Universal Fuel Company is making coke from the Big Muddy or Carterville coal, and as far as I know that is the only Illinois coal that is practicable for that use.

Mr. Schaefer—I might perhaps say that I understand the Universal Fuel Company did, for a while, make a very nice coke. I think it was used by the Illinois Steel Company. The analyses made of washed coal from the Carterville district seem to show that it is perfectly practicable to make coke out of Illinois coal. I expect some day to see a great coking industry down there.

Mr. Rice—Probably one reason it might not succeed would be that, even if the sulphur is low enough, the coke could not enter into competition with cokes that are made in the immediate vicinity of the mines. This was meant as an experimental plant, I understand, merely to see whether they could make coke. They would hardly be in a position to compete commercially with the coke coming from the eastern ovens located right in the coal fields.

Mr. Finley—Would not the cost of transportation operate against the eastern coke?

Mr. Rice—One would have to be familiar with the rates. The long distance tariff is very low. Even at the best, the coal coming from the southern part of this state is not as good as the eastern oal. The modern foundry practice requires a coke of the densest kind to withstand the burden, and that is not met in the ordinary Illinois coke. It may possibly be made in the future by an oven in which the coke structure is made denser. The ovens of the Universal Fuel Company are the ordinary beehive type with certain attachments.

Mr. Finley—I would like to ask Mr. Schaefer if the cost of coal is enhanced where the ash is reduced (say) one-half by washing.

Mr. Schaefer—It enhances the cost of the coal in two ways: First, in the actual cost of running the plant. That is a quantity which varies with the constancy with which the plant is operated. In one case in Pennsylvania, where they ran a plant day and night, for a long period of time, not interrupted by strikes, six days in the week from Monday morning to Saturday night, 1600 tons every day, their cost of washing, including repairs, fuel, oil and labor, was 3c. a ton.

Second, in the refuse matter rejected. You are losing that quantity. You have to count that into the cost of washing. That usually amounts to approximately the reduction in ash.

These two elements make up the cost of washing.

Prof. Kerr—I would like to ask what effect the washing has on the coal.

Mr. Schaefer—The evaporative power of the pure coal is very little affected by going through the washing process. The coal does not actually absorb moisture, and if it is thoroughly drained it is not affected.

In shipping coal by the carload it is customary in some places, where the distance shipped is not great, so the coal comes pretty fresh from the washing, to allow a certain number of pounds per car for water.

Prof. Kerr—About how much water would there be per car?

Mr. Schaefer—There would probably be in a car of wet coal—a 30 ton car—a ton of water. That is free water on the outside. The coal would not absorb the water, and within a day or two this water will all have drained off.

Mr. Rice—I can add but little to what Mr. Schaefer has said, but I think I will cite a practical case in which I was interested several years ago. At that time I was interested in the operation of the Ladd mine. This being a long wall mine there was a good deal of clay mixed in with the coal as loaded on the cars. This clay mostly goes in with the screenings. These screenings, at the time I speak of,—about five or six years ago—would not sell readily in the Chicago market. They tended to clinker very badly. We were interested in extending the use of this coal in Chicago, and tried to get one of the local buildings—The Rookery—to use some. The Rookery building people were unable to use it at all; it clinkered so badly that they nearly had to shut down the plant, and the matter was then dropped. We became interested in looking up coal-washing and made some experimental jigs and washed a few cars of the Ladd coal screenings. We then got the Rookery people to try it again. They burned it very successfully, were very much pleased with it, and wanted to get more. I took samples of the coal before it was washed, and while my recollection is a little uncertain, my remembrance is that the ash ran about 16 to 18 per cent before washing, and after washing it was in the neighborhood of 8 per cent. I do not think it was as thoroughly washed as if it had gone through a Luhrig washer, but it made it possible to burn the coal under the boilers without formation of clinker, and that in a furnace which is very severe, as it is extremely hot and would tend to produce clinker if any furnace did.

Mr. Finley—How much did that add to the cost?

Mr. Rice—That was merely an experiment. I simply built a couple of jigs and the handling was largely done by hand. I think the cost was approximately 5 or 6c, exclusive of the waste. I remember that at the time we made the analyses, the coal as mined carried normally about 8 per cent of moisture, including both what was chemically combined and that held in the pores of the coal. In sending the washed coal to Chicago the cars were two or three days on the road, and my remembrance is that the moisture ran about 10 per cent when used.

Mr. Schaefer—We want to get the right conception of what makes clinker. In one way it takes a good coal to make clinker. I know of a coal in the Black Hills which contains a very large amount of ash and sulphur. That coal makes very little clinker. The ash is fine like sand. I know of another coal in the State of Washington, the analysis of which is almost the same as that of the Black Hills coal, that makes a terrific clinker, and in the furnace where they were burning the coal, the clinker actually formed a ledge, and about two or three times a year they had to chip it off and reline the furnace. The coal in the Black Hills was not hot enough to melt the earthy matters together. The coal out at Washington was hot. It takes heat to make clinker.

I saw a fireman tugging with a clinker at the bottom of a Murphy furnace a few days ago. I said, "How much ash is there in the ash pit?" He replied that there was hardly any. He pulled the clinker out and when it cooled off it fell all to pieces. The fire was very hot and the little earthy matter in that coal was melted together into a pasty clinker by the terrific heat, but when it cooled off it fell to pieces. The coal was a washed coal.

Mr. Finley—Of the Black Hills and the Washington coals, I understand the Washington is more efficient.

Mr. Schaefer—Yes, it raises more steam.

Mr. Rice—It seems to me Mr. Schaefer has touched on another point. Something we really do not know about; viz., what effect the chemical constitution of the ash or the earthy matter of the coal has in forming a clinker.

Prof. Kerr—I heard a young engineer say, not long ago, that he could make clinker burn, by getting the fire hot enough. Is that possible?

Mr. Schaefer—No; the clinker material is incombustible.

Mr. Bement (by letter)—There is one feature in connection with the popularity of washed coal that is quite generally overlooked—that of the influence of the size; especially with the use in automatic stokers. It is frequently the case that screenings run so high in duff or extremely small coal that the air does not well enter the mass, and the coal burns slowly, with the result of a decreased horse power output, and with the consequent troubles therefrom. Under such conditions washed coal, which is of an uniform and proper size, will burn freely and uniformly, and almost always credit is given to the washing process, when, in reality, the satisfactory performance is owing to the size of the pieces, which in very many cases, especially with chain grates, the performance would have been just as satisfactory if the coal had been sized only and not washed at all. But as the general practice has been to both size and wash the coal, and as this manufactured product is always known as washed coal, the washing gets the credit.

It would be to the advantage of both the coal mine operator and the user if there was a satisfactory outlet for the dust, or a part of it, and it is probable that coal dust firing will afford this desirable outlet for what is more or less a troublesome product to both mine operator and user of screenings.

Closure by Mr. Schaffer—I would call Mr. Bement's attention to the fact that relatively but a small amount of the coal below egg coal size is sold as "screenings." All up-to-date tipples at the present time, that do not send their screenings to a washer, are equipped with appliances for separating these screenings into nut, pea and "duff." His statement that "washing gets the credit" for what is properly due to sizing is therefore hardly warranted by the facts. Sizing does aid combustion and nearly all washing plants size the coal either before or after washing, but, while a ton of sized coal has no more heat units than a ton of unsized coal, a ton of washed coal has much greater heating capacity than a ton of the same coal unwashed and of same size. The table given above, showing the reductions in ash in washing various coals, is instructive in this respect.

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CXXXIV.

PROTECTION OF WATER PIPE FROM ELECTROLYSIS.

By E. B. Ellicott, M. W. S. E., City Electrician, Chicago.

Presented November 6, 1901.

The absolute necessity for a constant and adequate supply of reasonably pure water has been demonstrated in all large cities. The methods and means of securing such a universal necessity have attracted the attention of the best engineers in the country, and there is no city large or small that has not given the subject careful thought and consideration. Millions of dollars have been expended in securing the supply and providing the necessary distributing system in the different cities and the expenditures for this purpose must continue as the population increases. As a rule, the distributing system is the most expensive part of the equipment and as vital in its functions as any other portion. Should any possible danger threaten this important part of the equipment, it would seem but the exercise of common sense and safety to give due consideration to the source of danger, and, if possible, remove it. It is useless to deny that such a danger can and does exist in many large cities where electric street railways have been installed on what is generally termed the grounded-return circuit system—many water mains showing plainly the effects of electrolytic action have been unearthed, and the responsibility for the damage placed upon the street railways—the only source from which this particular damage could come. The courts have passed upon several cases and the testimony upon the subject would fill volumes. It is interesting to compare the opinions of different competent experts who have served as witnesses or given depositions in the cases, for in most instances their opinions were directly opposite and favoring the side of the controversy which they represented. After all conflicting testimony had been given due consideration, the one undeniable fact still existed—the holes had been eaten in the sides of the pipes at points where they intersected with or were parallel to the street railway rails. It does not follow that such relative positions of pipes and rails will always cause appreciable damage—there are other attending conditions necessary, as will be shown.

When a current of electricity is caused to flow through a conductor of any kind, there is loss of current due to the resistance of that particular conductor. Until you reach the capacity of the conductor this loss is practically proportioned to the amount of current carried. For instance, if the capacity of a conductor was 100 amperes and but 50 amperes at 500 volts were passed through it, the loss would be one-half of that with 100 amperes at 500 volts. As the loss also varies in proportion to the voltage, 100 amperes passed through a conductor at 250 volts would represent twice the loss at 500 volts. Place two conductors of the same resistance and capacity together and the loss in either instance will be one-half, with four similar conductors, one fourth. This could be carried on indefinitely and the loss would always be proportional. If the conductors placed together are not of equal resistance, the current will divide itself in proportion to the relative resistance of each conductor. The grounded return system represents this placing of conductors together, and following the known law the current divides itself into as many parts as there may be conductors offered for it, and in quantities varying with the resistance of each conductor. The rails form in most instances the better path, especially when they are reinforced with copper cables connected at intervals to the rails. As these rails are in contact with the earth, which is also a conductor, some of the current must pass through it, and if there any heavy metal pipes placed in the earth and near the rails, the pipes form a conductor of less resistance and the current naturally seeks it in its endeavor to reach the generating station, by the line of least resistance. As the conducting medium between the rails and pipes is composed of the earth, which has a comparatively low carrying capacity, a considerable section is required to carry a small amount of current between the two better conductors. Where the pipes parallel the rails, the section of earth offered the current in its passage is very large and the current is divided to a great extent throughout the distance they are parallel, passing from one conductor to the other in proportion to the varying relative resistance offered by each conductor. Diagram No. 1 shows a very common condition existing in Chicago. A certain section of the rails will be well bonded and reinforced by copper cables affording a path of low resistance, while defective bonds and lack of copper cables will cause higher resistance and a poor path in one part of an otherwise good return circuit. The current reaches this high resistance and is forced to seek an additional conductor. This it almost invariably finds by leaving the rails and following the water pipe, to bridge over the high resistance in the rails, returning in part to the rails when that particular resistance has been overcome.

At the point where the current leaves the pipes to return to the rails or find another or better conductor, the city of Chicago becomes interested. When a current of electricity is caused to passed from one piece of iron to another, both of which are connected by a conducting medium containing salts, such as are ordinarily found in the earth, a chemical action takes place and is made apparent by an oxidation on the surface of the iron from which the current leaves. If this action is continued the iron becomes porous and can be cut with an ordinary knife, and in course of time holes will be eaten entirely through the pipe. One peculiarity of this electrolytic action is that it increases rapidly, due to the saturation of the earth with particles of iron carried along the path through the earth followed by the current in seeking the rails or other conductor forming a lower resistance path.

As the earth becomes partly saturated with particles of iron it becomes a better conductor, more current passes and the disintegration increases. Where this action has taken place between lead pipes and the rails particles of lead have been seen in the earth with the naked eye, and chemical analysis will show the presence of lead and iron some distance from the point where the electrolytic action took place. During the last three years many pipes have been removed that showed unmistakable signs of electrolytic action and as the subject is one of great importance to the city a careful examination has been made of the surrounding conditions. The greatest disintegration has taken place at points where the pipes were placed at right angles to the rails. Another attending condition has always been present—there was a greater difference of potential at that particular point than at any other in the immediate vicinity, indicating that the current was centering at the point where the chemical action was taking place. Disintegration would invariably be found in two or three feet of the pipe, the balance showing no signs of injury. Now if serious disintegration is always found where there is a marked variation in the potential indicated between the pipes and rails, the pipes showing positive, it would seem reasonable that a minimum and perhaps inappreciable amount of chemical action would take place if a uniform potential was maintained between the pipes and rails throughout the entire system. Theoretically this condition would distribute the chemical action evenly throughout the entire length of the pipes, and, if the maximum difference of potential is within reasonably safe limits, the disintegration would not materially shorten the life of the pipes. There would necessarily be some disintegration, but it would be inappreciable.

Results in this city indicate that this theory is correct. While there is a variation in the resistance of the earth, which would have the effect of causing more current to flow at one point than another, the same difference of potential being maintained, it is not probable that any serious trouble would ensue. Surveys of several miles of tracks and pipes laid parallel to each other prove that if the condition of uniform difference of potential exists no appreciable damage has occurred, while examinations of pipes where a marked variation exists almost invariably shows serious disintegration of the iron.

With a view to adopting a system based on this theory the city council passed an ordinance requiring that grounded return circuits should be so constructed that a greater difference of potential than 3½ volts should not exist at any point between the water pipes and rails and the variation between any two points within 300 feet should not exceed one-half volt. The requirements of this ordinance were based on the results of the two years' testing and examination of existing conditions, and in two instances have been accepted by companies in extended franchises. It seems to be a reasonable regulation and one that can be complied with under any ordinary circumstances. But there are conditions in Chicago that are not ordinary. The surface lines returns were designed with a view to using their rails and a certain amount of additional conductor in the form of copper cables bonded to the rails at certain points. If some particular line showed additional loss it would be a simple matter to reinforce it. When the elevated roads with their massive iron structures were constructed they formed a new factor in the return circuits. At many points they intersect and in some instances run parallel to the surface rails, presenting in part a better path for the return current than either the rails or water pipes. The current is thus diverted from its own return to a foreign one, which it leaves when another and better conductor offers itself. This diversion of the current brings about conditions which make it almost impossible for any one company to correct its own faults regardless of the conditions of the other, for there is no practical manner of identifying the current which is seeking a water pipe for a conductor. There is no important surface line that is not intersected or paralleled by some one of the four elevated lines. As all the elevated lines use electric power and carry their return current on the structure there is in some instances a diversion of their current to the surface rails and pipes.

Thus it appears that notwithstanding the fact that the trouble can be located, and a practical remedy applied, it requires a combination of efforts of all the companies using a grounded return before any satisfactory solution of the conditions can be arrived at and the disintegration of pipes reduced to a negligible amount. In the process of time the entire question will come before the courts and if the precedent means anything, some adequate relief will be awarded. In the meantime careful tests are being made where there is any sign of trouble and samples of pipes showing the disintegration are preserved with the proper records.

General practice seems to be the only excuse for using a grounded return circuit. The proper construction would be to mantain a separate return circuit insulated from the ground. To require this change of construction on existing systems would mean a radical change in the entire equipment and while it would be a desirable relief from our present difficulties it is probable that satisfactory results could be obtained by the co-operation of the different companies, on the basis of maintaining a uniform difference of potential between the rails and pipes throughout the entire system. Diagram No. 2 illustrates what is meant by a uniform difference, and if such a condition was maintained the chemical action would be distributed evenly over the length of pipe subject to carrying the current, varying only at such points as there might be a difference in the resistance of the earth, or less distance between pipes and rails. Such variation would not be serious and would exist in but few places.

Diagram No. 3 shows a condition that indicates an unequal chemical action. Under ordinary conditions five times as much current as at point of one volt, would be passing from the pipe to the rails at the point indicated by five volts, and with certain conditions of excessive current on the rails a rapid disintegration would take place, while at the point marked one volt there might not be any appreciable injury. There are hundreds of conditions in Chicago similar to that shown in diagram No. 3, and they are occasionally developing serious injury to the water pipes. These conditions will continue to exist until the different companies join interests and take the subject up as a whole and reconstruct their return circuits, supplying additional conductors where necessary and bonding between the different systems at points where one forms a partial circuit for another.

The city council does not appreciate the existing conditions, and it has been impossible to secure an appropriation for the purpose of carrying out a full survey of each line of pipes that are in a position to be injured. Plats have been made of the surrounding electrical conditions of about 15 miles of pipes, but this is only a small part of the work to be done. The indications are that in a comparatively short time, perhaps two or three years, it will be a matter of regret that the subject did not receive the attention it deserves. There is no reason to believe that this city will be less subject to trouble from this source than other cities, and there are numerous instances of serious injury to the water pipes where the existing conditions were much better than in Chicago. We have Dayton, Indianapolis and Peoria for examples of what to expect. When the time comes for settling the damage the city will certainly win, but protection to the water system is what we want. The individual companies have, as a rule, given attention to complaints of dangerous local conditions, but the remedies have been local, while they should be general in character. There seems to be no interest on the part of the companies to take the subject up as a whole and settle it to the best interests of all concerned. In all probability the city will have to resort to the courts, where the precedent established indicates that ample protection will be furnished.

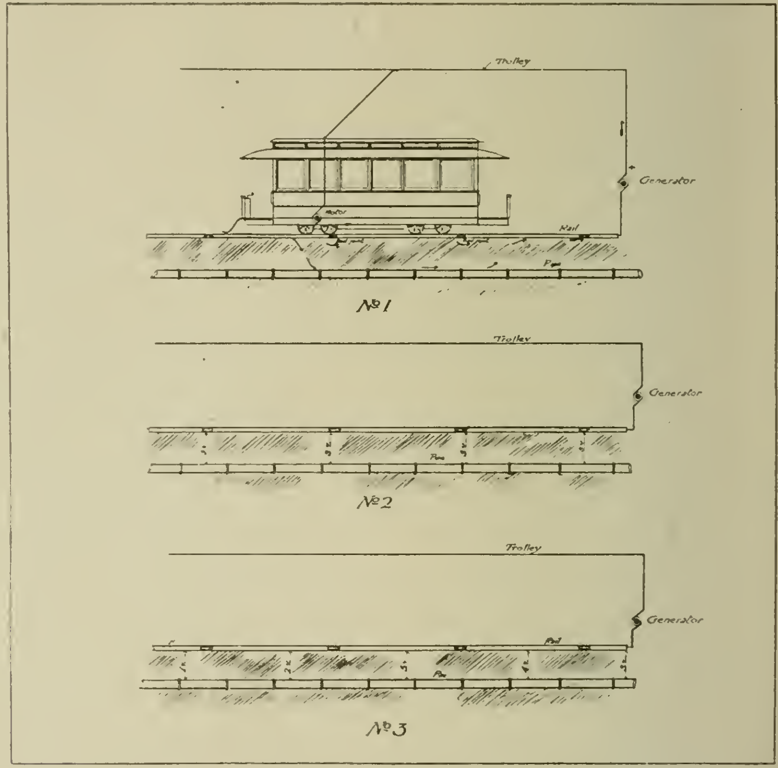


Diagram No. 1.—Showing where the high resistance comes in, at different joints. The point where the current leaves the water pipe is where the City of Chicago becomes interested, as that is the point where the damage is done.

Diagram No. 2.—Showing the theoretical condition that should be maintained. If the difference of potential power between the rails and pipes is maintained evenly throughout, the amount of current that is caused to pass from the rails to the pipes would be distributed over the entire length of the pipe. The chemical action would not then be confined to some particular point, as is now the case. Experiments have been made (using the existing conditions as they would in an ordinary city) which indicate that 10 pounds of iron will be decomposed in 1,000 hours by the flowing of the ampere of current. These experiments were made by one of the professors of a college and are accepted as being correct. On that basis, if we maintain an even difference in potential between the rails and pipes throughout, it would take hundreds of years to decompose enough of the iron from the pipes to weaken them, provided it was decomposed from the entire length of the pipe, as it would be with the conducting medium of the earth, which has practically the same resistance throughout any ordinary distances such as are found in the City of Chicago.

Diagram No. 3—Shows a condition that exists in Chicago in a good many places. I have on record over 100 places where similar or worse conditions exist. They are usually found at or near a power house. The point marked "one volt" is a place near the end of line. There the difference in potential is very small; it increases on getting nearer the power house; when it reaches a point very close to the power house it is very close to 5 volts; when it gets past the power house it is 4 volts, and continues to decrease the farther it gets from the power house. At the point marked 5 volts, is where we find most of our trouble. If we can remove those conditions and make the voltage more uniform throughout, or practically so, we shall not have the centering of the current and the excessive chemical action placed at one point. It would make no difference to the railway companies, because the total loss is the same. We have, say, 15 volts less in the total length of that line; on the other diagram, we have 3 volts at each point, making it the same, so it would mean no more to the companies and means better distribution of chemical action, and that is a condition we are contending for in Chicago.

I have here a report of conditions, made in 1898. It is a copy of a letter to the Commissioner of Public Works. This report is the one on which we based our theory that an even difference of potential would remove any serious difficulty. That theory, up to the present time, has not been argued very extensively. As far as I am personally concerned, I would be very glad to have the matter discussed most fully, and if there is anything wrong with it, I shall be much interested in knowing where it is. I am seeking for light on this subject as much as any one else in the country. The very best engineers have had a chance to investigat eelectrolysis in different cities. Omaha has made a very extensive report, but they have not been able to settle the matter, however. Dayton is in practically the same condition. Also Indianapolis, Brooklyn, Peoria and Denver. They are all at sea. While I feel very much like offering an apology for selecting a subject that has been threshed over so much, I think it is a matter that a free discussion would help considerably, and I would be very glad to hear from any one on the theory that has been advanced, and in a way has been adopted, by the city of Chicago.

DISCUSSION.

Mr. Grant—I would like to ask Mr. Ellicott if the gas companies have any trouble with their pipes.

Mr. Ellicott—They experience the same difficulty that we do.

Mr. Grant—Is the matter being remedied now?

Mr. Ellicott—There is nothing being done as a whole. Only on the local reports that are made.

Mr. Grant—To what extent does the trouble occur? How large are the holes?

Mr. Ellicott—We found, in some instances, holes that were 3 inches in diameter; in other instances, several holes of from ½ to ¾ inches. We have one or two samples of pipe in which the top part of the pipe was entirely eaten away for a space of a foot or 18 inches.

Mr. Grant—In how large a pipe was that?

Mr. Ellicott—The pipes that were entirely eaten away were 2 inches; the ones where we found 3-inch holes were as large as 6 inches. There was one 8-inch pipe with a hole about 2 inches in diameter, and several holes nearly eaten through, about the size of a dollar. These were all comparatively new pipes and in use at the time.

Mr. Grant—How could the hole get so large without its being discovered?

Mr. Ellicott—The pressure of the earth was enough to hold the water back. Of course, it had been leaking, but this leakage was not apparent until it broke through the top of the earth. In some instances it takes a long time to break through.

Prof. Chamberlain—Have you observed any difference in the action on cast and wrought iron pipes?

Mr. Ellicott—The wrought iron pipes show damage before cast iron pipe under same conditions.

Mr. McCulloch—There has been such overwhelming evidence presented in this paper as to the wickedness of street railways, that

I feel a little timid in saying anything. Mr. Wellington, in his "Theory of the Location of Railways," states that it is an unfortunate fact that any ordinary individual provided with nothing but a surveying instrument and a knowledge of the elementary laws of geometry, can lay out a railway, and it is a still more unfortunate fact that such a railroad will operate, and will operate to all outward appearance just as well as a railroad built with the greatest skill. It is not like a badly built bridge, it does not fall down. It is not like a badly built engine, it does not refuse to work. Street railroads have been peculiarly unfortunate in this respect. A great many of them which were built a long time ago were built without any regard for Ohm's law or any other physical law. The calculations as to the necessary feeder capacity and the proper location for feeders were replaced by a sort of intuition on the part of the builder, but it is hardly necessary to state that this intuition rarely led him to install too much feed wire. At present the large railroads, and certainly the large and progressive ones, make as much a study of the question of electrolysis as the water and gas people, and we are just as anxious and just as ready to remedy any defects as the companies which own the water and gas pipes. We are willing at all times to co-operate with them, either in determining what is necessary to be done or in applying the remedies. I think that most of the trouble is confined to the smaller towns where lack of money or lack of enterprise has prohibited the necessary maintenance, or perhaps the necessary construction in the first place. I did not know, until Mr. Ellicott so stated, that we had such a condition on our system. I thought we were in pretty good shape. We watch that pretty carefully and try to determine the conditions and when we have determined these, we try to remedy them. We have, going out of our different power houses, a much larger section of copper wire on the negative side than on the positive, and in addition to that we have a well bonded track, and we try to maintain it in that condition. I think the combination of a well bonded track and feeders of ample capacity, located in the proper places, form the surest preventative for electrolysis. With reference to Mr. Ellicott's theory that the maintenance of a uniform potential at all places between the track and the water pipes would prevent electrolysis, this would be all right if Mr. Ellicott could choose the kind of earth in which he puts his pipe. The amount of current which flows from the pipe to the rail does not entirely depend on the difference of potential which you find between the pipe and rail. It depends on the conductivity of the electrolyte. We have a number of different kinds of earth here in Chicago. Some of it is almost pure sand, in which I think there is very little electrolysis. In other places we have streets which are made up of garbage, in which there is a great deal of vegetable and organic decaying matter. That forms a good electrolyte. I do not know wheher it will be interesting to you, gentlemen, to know the methods which we pursue in studying this question or not, but I have found that the best method of determining the conditions in the neighborhood of the power house is something like this. (It is in the neighborhood of power houses that these troubles are likely to occur.) We run a pressure wire on the poles parallel with the track for about a half mile from the power house. To one end of this wire we connect the negative bus bar, and at different points along the wire we insert a recording voltmeter. This voltmeter gives the variations in pressure which occur at all times of the day. It is necessary to make a great númber of observations, because a single observation is misleading. One reading of voltage might be very erratic on account of the passing of a car or on account of the fact that there is a light load, so we take that reading over a long period of time, and using these readings as a basis we make a contour electrical map. This shows the conditions in the neighborhood of the power house as closely as they can be determined, and by studying it we we can see where additional feeders are necessary,and what their capacity should be. I think that, as I stated, the surest preventative for electrolysis is the combination of a well-bonded track and a good connection between the power station and the rails, being careful at all times that the capacity of the rail is not exceeded. I think that the troubles that have occurred are due more to negligence and carelessness of maintenance than they are to any inherent defect in the grounded return.

Mr. Ellicott—Do you know, Mr. McCulloch, what your rail bonds are on Indiana Avenue?

Mr. McCulloch—They are No. 00 wires. I do not know exactly the type of bonding.

Mr. Ellicott—Do you know the relation of the carrying capacity of these bonds and the rails?

Mr. McCulloch—No.

Mr. Ellicott—You speak about a well-bonded track on that street. You happen to have a No. 000 bond, which has a carrying capacity of something like 200 amperes without getting very hot. Your rails have a carrying capacity of something like 1,500 amperes. You use something like 450 to 400 amperes over the rails. How do you reconcile the bonding you have on that system? That is just one of the cases that brought up this paper to-night. You have pretended to properly bond your rails, but you have not done so because they have not the proper carrying capacity. You know that there is not enough with the No. 000 wire. There was a light load when we took our measurements. You have only provided for a couple hundred amperes on each rail. In the course of a month if you dig down you will not find one bonding in ten that is in condition for doing its work.

Mr. McCulloch—That will be news to our track department. As to Indiana avenue, I will state that it is our intention to cast-weld all that track. A cast-welded joint, well made, is equal in conductivity to the rail, and in addition to the cast weld we bond around them, so in case the weld should break, the joint still maintains its conductivity.

Mr. Ellicott—In referring to this test on your line I intended to cross out the name, but the rest of the report goes on to say that, "later I requested them to disconnect one of their long feeder lines extending from 22nd street to 51st street to allow us to make a test of the conductivity of the rails. I found there was a drop in potential between 22nd and 51st streets of 12½ volts at three o'clock in the afternoon, when the load was comparatively light." Your company remedied that condition inside of 24 hours, bringing the potential down to 4¼ volts, when it was 12½ before. It took two hours to do it. The remedy was local in character, but you did not go over on the next street and do anything where the condition was practically the same.

Mr. McCulloch—If we had had the same information we would probably have done the same thing.

Mr. Ellicott—You must not find fault when we appear before a society of this character and state that you have not done so. It is impossible for us to notify the different companies of all the defective places.

Mr. McColloch—I do not think we are any more culpable than the rest of them.

Mr. Ellicott—Not a bit. I stated that you were not.

Mr. Tratman—Some reference has been made to the cast-welded joint as a remedy for defective or insufficient bonding, but this joint is not necessarily better than any other style of bonding, and tests on old cast-welded joints have shown that they are often pretty poor conductors with very considerable leakage. While in Cincinnati a few weeks ago I was observing the double trolley system. I had always supposed it must be a very clumsy arrangement, but you hardly notice it on the cars and the trolleys seem to stay on the wires even better than in the single trolley system. I very rarely saw them come off. That, of course, does away entirely with the trouble with the track return and is presumably less expensive than the conduit electric system, while it can be installed on existing trolley lines without trouble. As to the bonding of the joints, I have never yet heard of any make of bond that had been in service a few months that had anything like the conductive capacity of the rail, especially on a long stretch of track. Of course, certain individual joints may be well bonded. I would like to know whether Mr. Ellicott has made any observations on any cast-welded joints, or whether he has ever found any kind of a rail bond with a capacity equal to the rail? I do not mean a new joint, but one that has been in use. I think the street railway companies should pay very much more attention to the bonding of the joints, and to the testing, maintenance and renewal of the rail bonds in service.

Mr. Ellicott—We have never yet found a rail bond in Chicago anywhere near the capacity of the rail or that the rail was obliged to carry. I did make some tests about two years ago on a new cast-welded joint, and found that the conductivity of one joint was practically that of the rails. (We used the differential system.) But we also found two other joints where the capacity was not half the conductivity. There was a variation in the manner in which they made the cast-welded joint, due to some method of cleaning the joint. We found it necessary to drill holes in the rail and fill them with mercury, in order to get any kind of a measurement.

Mr. McCulloch—Some years ago I made a number of tests myself of cast-welded joints which had been in the ground three years. We sawed the joints out, passed a large current through them and measured the drop. The average of tests of a large number of these joints showed that the joint had a conductivity of about 80 per cent of the rail. Now, the integrity of a cast-welded joint and its conductivity depends entirely on how it is made, and on whether the joint is clean. If all the rust and dirt is taken off before the iron is poured and the iron is poured very hot, the joint is good. If it is not clean it will not be a good conductor. I know positively that a cast-welded joint can be made which will be equal to the conductivity of the rail, because I know a man who is doing that thing in Europe He has a contract for about 10,000 joints, and guaranteed that each one of these joints should be equal in conductivity to the rail, and each one of his joints is tested. The railroad companies take a great deal of care, in Europe, with contracts that they let out, and each one of these joints is tested by means of a large storage battery carried around on wheels. Every joint which is not equal in conductivity with the rail, even if it has a conductivity of 99 per cent, is rejected and must be sawed out and a new one made. I know it to be a fact that cast-welded joints can be made whose conductivity is equal to the rail.

Prof. Kerr—I would like to ask if the underground trolley has any advantages in regard to this question of electrolysis?

Mr. Ellicott—That is a pretty delicate subject to discuss with a representative of the railway company present. It is too bad that we have to admit that that would eliminate the trouble. In the underground system they use the copper return circuit without any connection to the earth whatever, and there is no danger of electrolysis.

Mr. W. L. Abbott—After listening to Mr. Ellicott's paper, one thing has occurred to me, and that is that he did not suggest any remedy for the roads as they now exist. He suggests the return circuit—that is, the double trolley—but what would he do to remedy the present condition without resorting to the double trolley?

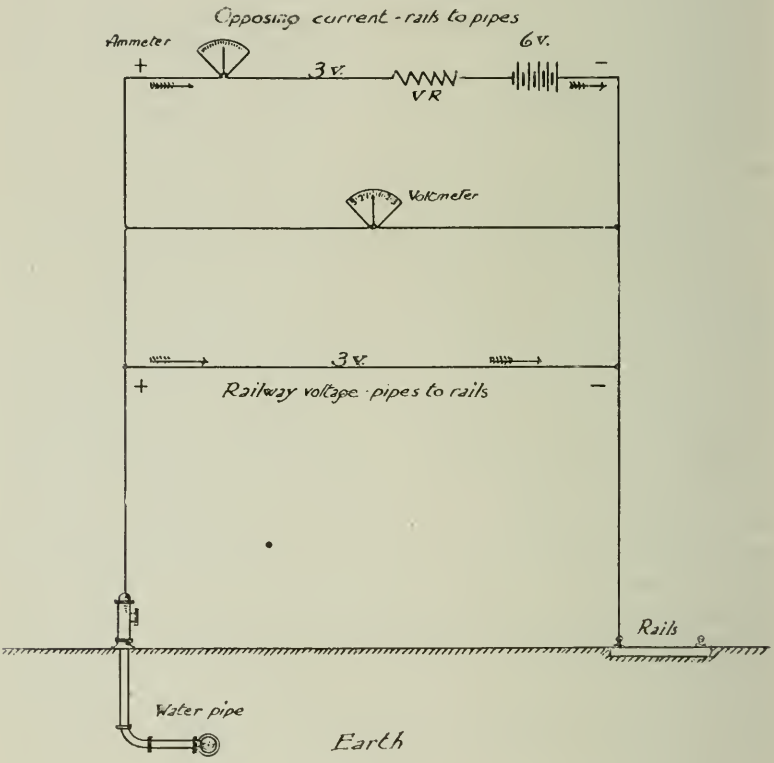
Mr. Ellicott—The theory I advanced was that if we were to rebuild the return circuits of all the railway companies so there would be a uniform difference of potential between pipes and rails throughout the entire system, the chemical action would be extended over the entire system and not to one or two points. Now, that would be practicable with the present car lines, and they would not have to make very many changes. At present we find in one place 16 or 18 volts, while in another place we will find one volt indicated. It is a condition that should not exist and I think that the theory outlined would, if properly applied, overcome all difficulties. Mr. McCulloch has said that the difference in the resistance of the earth is such that you cannot depend on a uniform difference of potential as a protection; but our tests indicate that there is not to exceed 20 per cent. variation in the resistance of the earth throughout Chicago. We make our measurements from the amount of current flowing. He also said that the mere indication of potential between the pipes and rails does not mean that current is flowing. Our method of measuring that is to build up a current against the voltage as shown between the pipes and rails, that is, build up twice the current in the opposite direction. For three volts we build up three volts positive current against three negative, and three volts additional, and then the current which flows with six volts will give us the amount of current that was flowing through the earth with the original three volts. It makes practically a bridge of an ammeter.

Mr McCulloch—Then you measure the current and not the potential.

Mr. Ellicott—No, we take the potential into consideration. We build up a circuit of six volts in the opposite direction. If the pipes are positive to the rails, we place our current negative to the rails. The current that six volts will cause to flow through the doubled resistance is equal to the amount that three volts should pass through the earth. I think you will find this is correct.

Mr. Abbott—How would you maintain an even potential between the rail and water pipe? This difference of potential is proportional, of course, to the current flowing and to the resistance. At the end of the line where there is no current flowing there would be no difference of potential. At the power house, where the volume of the current is great, there would be the greatest difference in potential. It seems to me it is an impossibility to maintain any other than an even drop from 0 at the end of the line to the maximum difference at the power house.

Mr. Ellicott—I have not stated that it should be absolutely even throughout. They can start with practically nothing at the end of the line, as they naturally would, but when they get down toward the power house we do not want them to have 15 volts between the pipes and the rails. We do not care if, in the full length, they have had a fraction of a volt, in every 300 or 400 feet, as that would practically insure that the chemical action would be extended over enough of the pipe, and no serious injury would be done.


Opposing current - rails to pipes
Ammeter
+
6 V.
–
3 V.
VR
Voltmeter
3 V.
+
Railway voltage · pipes to rails
–
Rails
Water pipe
Earth

No. 4.

Mr. Abbott—Instead of even potential between the rail and the pipe, you mean the difference in potential in a block should not be more than one-half volt, do you not?

Mr. Ellicott—So I stated; that is the wording of the ordinance. We do not want a marked variation, in the immediate vicinity of any one point. In the instances I spoke of and which Mr. McCulloch spoke of also, on Indiana avenue, we found it in a space of 40 feet. It took a couple of hours to renew their bonding, and they eliminated eight volts of the drop. They could do this in any other place where such a marked difference occurs.

Mr. W. H. Pearce—I would like to ask what is the resistance of the earth.

Mr. Ellicott—It is a pretty hard thing to measure, especially in the vicinity of the rails. We have tried several times to get a measurement. A Wheatstone bridge does not give any results on account of the current working in opposition to the battery. It is a very small fraction of an ohm in eight or ten feet.

Mr. Pearce—Do I understand this is eight or ten feet for one foot in cross section? What would be the area in cross section?

Mr. Ellicott—The current in the ground is usually flowing in the shape of a double-ended heart—wider in the middle than at either point. I have never made any measurement of a cubic foot of earth, because you cannot get a cubic foot in its natural condition. You would have to measure a certain section of the earth as it exists, and I think the last test we had on it was one-fiftieth of an ohm for nine feet, and the points were driven down, I think, six feet. They were just one-half inch iron rods driven down. The resistance would of course be less per square foot of iron exposed to the earth. The amount of surface exposed has a good deal to do with it, so you cannot get a measurement that would be worth anything unless you could measure between the pipes and rails, which you cannot do because the instruments will not work well.

Mr. Seddon—I will repeat the question I asked Mr. McCulloch. That is, what is the objection to connecting the pipes with the rails?

Mr. Ellicott—We have never done it in Chicago. Opposition has been made in a number of cities to connecting the water pipes to the rails. In the first place, because the cities were not under any obligation to construct a return for the railway companies, and in the second place, on account of the joints in most cases being made with oakum filled with lead. They have claimed to have found chemical action with the lead caulking. We have never found that in Chicago. That is the objection made generally—the liability of disintegrating the lead where the pipe is joined together.

Mr. W. E Foss, of Metropolitan Water Works, Boston, Mass, (by letter)—The destruction of pipes and other metal structures buried in the earth, by the processs of electrolysis, was first observed about 10 years ago, soon after the introduction of the electric railway. The earliest investigations of the action showed that it was caused by the electricity which escaped into the earth from the rails of these electric railways.

The railway officials were soon convinced that the action was a result of the operation of their systems, and, admitting the fact, made some changes in the equipment and method of operating their roads, with the object of lessening the action and relieving the agitation of the owners of the structures. Some of the changes undoutbedly were beneficial and reduced the action to some extent, but the mitigated action has gone steadily on week after week and month after month, and the aggregate result is now serious in many places. Peoria, Ill., Dayton, Ohio, and Indianapolis, Ind., have already been referred to as a few of the places where a large amount of injury to pipes have been discovered.

Our experience on the Metropolitan Water District in Massachusetts, which includes the city of Boston and most of the cities and and towns within a radius of 10 miles, shows that this district might also be included in the list, as a large amount of injury has been found in the vicinity of all the power stations in the district.

In the double trolley system, either overhead or underground, and the storage battery system, the entire circuit is completely insulated so that no electricity enters the ground from electric railways operated by either of these systems.

The owners of the water and gas pipes are obliged to stop all leakage from them, and if the railway companies were obliged to stop the leakage of electricity from their systems some form of insulated circuit would have to be used, with the result that the electrolytic action would be stopped completely.

Almost all of the electric railways, which now extend over nearly every part of the country, are operated as single trolley systems, and with good bonding and careful inspection the large rails which are now in common use form a good return circuit which probably could not be duplicated for less than $6,000 per mile of single track.

It is probably on this account that numerous methods have been advocated by the engineers of the railway companies and other investigators, for lessening the action to such an extent that the objection to the operation of the single trolley system would be removed. Unfortunately none of these methods have been a complete success so that we are still seeking for a solution of the problem, and it may be of interest to discuss the probable results to be expected from an application of Mr. Ellicott's suggestions under the conditions existing in the Metropolitan District.

The erratic variations in differences of potential between pipes and rails shown on diagram No. 3 have not been noticed in our voltmeter surveys. There is usually a fluctuation in the difference of potential between the pipe and the rail at nearly every point from minute to minute and from second to second, averaging about 2 to 3 volts in the large and well equipped systems and much more on smaller systems with poor equipment, due to the constantly varying traffic. On this account it would be extremely difficult to decide whether the requirements of the city council's ordinance were being complied with.

Limiting the maximum difference of potential between the pipes and the rails to 3.5 volts would not be a solution of our problem, as considerable injury has been discovered where the electrical pressure does not exceed this limit. It is not evident how a constant difference of potential of 3.5 volts between pipes and rails could be maintained over the entire area of the Metropolitan District.

Diagram A

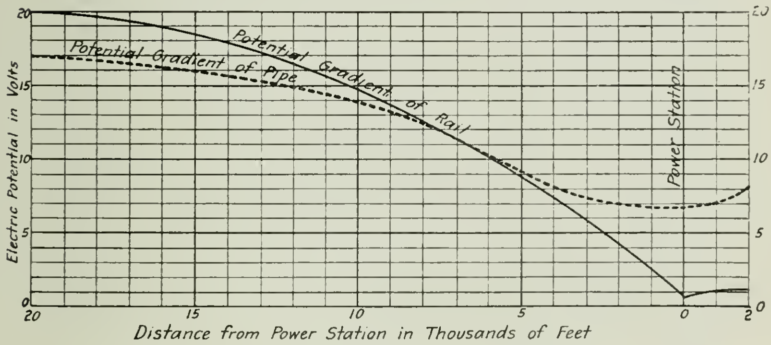


Diagram A is a graphic illustration of the prevailing relation between the potential gradients of the pipes and rails in the Metropolitan District as indicated from the electrical surveys which have been made at frequent interval during the past 5 years. It shows a gradually decreasing difference of potential between the pipe and the rail, with the rails positive in passing from the outer end of the system toward the power station until the neutral section is reached, where the difference is nothing; from this point to the power station the difference of potential gradually increases, the pipe being positive to the rail.

Measurements of the strength of the current flowing over the pipe at various points indicate an increasing current as the neutral point is approached from the outer end, and a decreasing current after it is passed. The increments and losses do not necessarily take place uniformly, but are often influenced by favorable local conditions along the line.

Diagram B is a graphic illustration of the probable effect on the potential gradients of broken or high resistance bonds in the track and of joints of high resistance in the pipe line.

From this diagram it may be seen that a broken bond on the track does not necessarily cause a flow of electricity from the pipe back to the rail. Whether a portion of the shunted current returns from the pipe to the rail is determined by the distribution of the electrical pressure.

An examination of these diagrams indicates that the most that could be accomplished would be to obtain a uniformly decreasing difference of potential in the negative districts and a uniformly increasing difference in the positive districts.

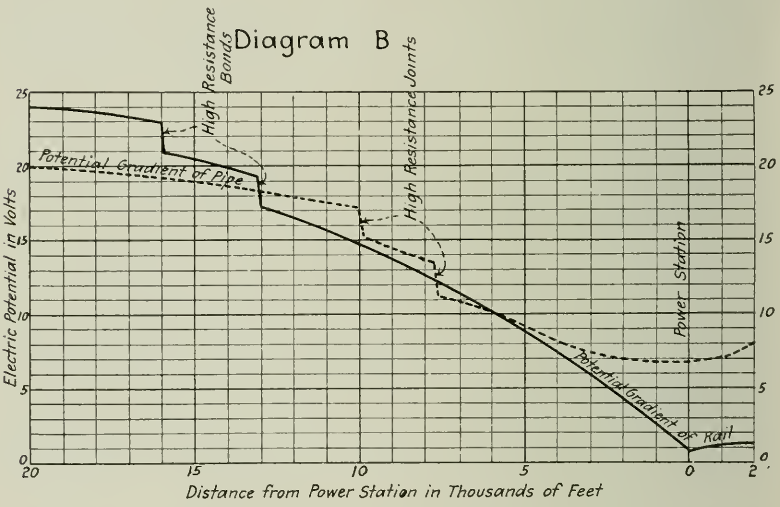


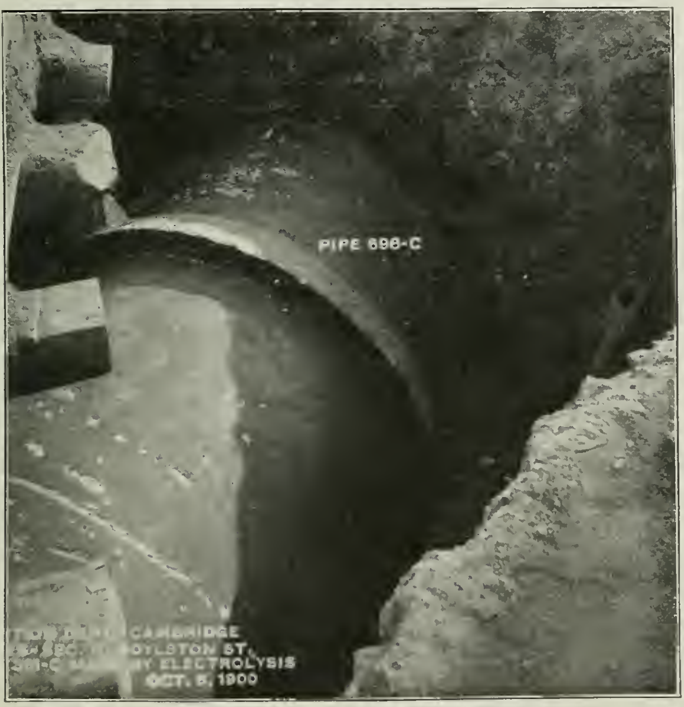
Diagram B

Several instruments for testing rail bonds are now on the market, and broken bonds or poor contacts at the rail joints can be detected with proper inspection, and repaired.

A simple arrangement for testing the resistance of rail bonds or pipe joints by Wheatstone's Bridge Method and using a millivoltmeter, which I have found gives satisfactory results, is shown on Diagram C.

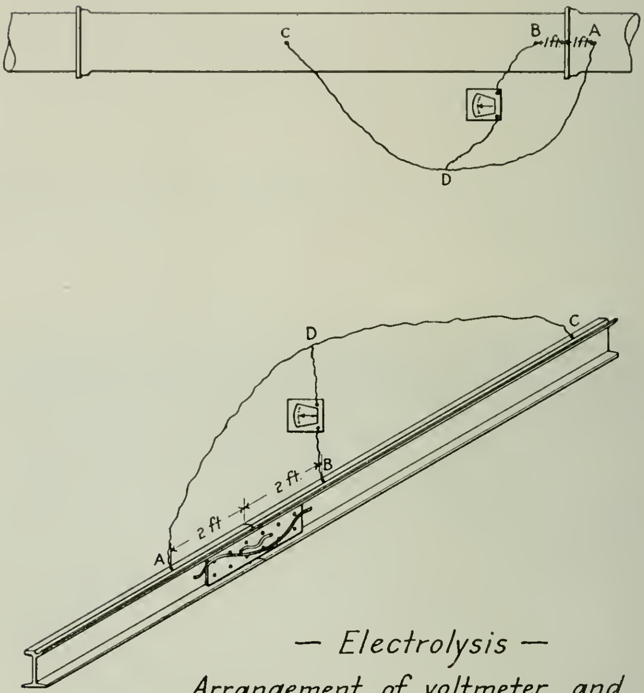
A portion of the current of electricity flowing on the rail from A to C passes through the shunt ADC, on which the resistance of the portion AD is equal to that of the portion DC, so that the potential at the point D is midway between the potential at A and at C. The points A and B are taken 2 feet each side of the joint, so that the resistance AB is the resistance of the bond plus 4 feet of rail. The point of contact C of the shunt wire with the rail is adjusted by moving it toward or away from the bond until there is no deflection of the needle of the voltmeter. When this balance is obtained the potential at B must be equal to the potential at D. Hence, it is midway between the potential at A and at C. The resistance of the length BC of rail is then equal to the resistance between A and B. The length BC is then measured and by subtracting 4 feet from this length the resistance of the bond in equivalent length of rail is obtained.

Our experience has shown that injury is due more to local favorable conditions, such as nearness of pipe and rail, low resistance of intervening earth and the condition of the pipe surface, and it has been noticed that the action is most severe at the sharp edges of pipe bells and at a line about 2 feet either side of the pipe joint.



We have never noticed that where the pipes are at right angles to the rails there is an increase in the electrolytic action. There is often action at such points because the controlling conditions, relative location of pipes, rails and power station frequently require that the current should leave the pipes at these crossings. The condition, difference of potential, character of earth, distance between pipes and rails, etc., being fixed, the decomposition of the

Diagram C



— *Electrolysis* —
Arrangement of voltmeter and leads for testing resistance of Water Pipe Joints and Rail Bonds.

Nov. 7, 1901.

DIV. ENGR

metal, which is directly proportional to the strength of the current, would be increased when the pipe is laid parallel with the rail, because the area of the cross sections of the conducting electrolyte being larger its resistance is less and more current will flow from the pipe to the rail.

The action of the pipe crossing the rails, although less in amount, is usually concentrated near the point directly under the rail.

CXXXV.

THE COEFFICIENT OF EXPANSION OF CONCRETE.

By Wm. D. Pence, M. W. S. E.

With the increasing use of concrete as a structural material, the demand for a definite knowledge of its physical characteristics becomes more and more urgent. Unfortunately concrete varies radically in quality with the character, proportioning and manipulation of its ingredients, and its so-called structural constants, such as the compressive strength or the coefficient of elasticity, which, in a sense, are an index of quality, of course suffer a like fluctuation. One constant, however, the coefficient of expansion, which probably varies but slightly, seems to have received scant attention in the laboratory, if one may judge from the dearth of published data on the subject. The purpose of this paper† is to throw some light on this point.

Scope of Investigation.—In planning the investigation it was at first proposed to determine the coefficient of expansion of each of a series of concrete bars differing both in the kinds of cement used and in the proportions of ingredients. It soon appeared, however, that considerable time would be required to perfect the apparatus, and it was early decided to restrict the first season's tests to a single brand of American Portland cement. In view of the fact that the investigation was suggested by the question of temperature stresses in the concrete-steel arch, it was finally deemed expedient to limit the scope of the investigation at the start still more closely and to direct attention for the time to a single grade or quality of Portland concrete representing best practice in the combined concrete-steel type of arch work. The selection of this standard of quality was simplified by the opportune appearance shortly before that time of a comprehensive article by Mr. Edwin Thacher, M. Am. Soc. C. E., entitled, "Concrete-Steel Bridge Construction" (Engineering News, Vol. XLII., pp. 179, 182, 202, Sept. 21, 28, 1899).

Concrete Bars.—Following is an extract from Thacher's specifications which governed the preparation of the concrete bars used in the investigation:

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† The experiments upon which this paper is based were conducted under the writer's direction by F. B. Ernst and R. W. Pearce (1899-1900), and by H. W. Brown and E. R. Houghton (1900-1901), as thesis work in the School of Civil Engineering, Purdue University, LaFayette, Ind.

> "PORTLAND CEMENT CONCRETE.—The concrete shall be composed of clean hard broken stone, or gravel, with irregular surface; clean, sharp sand, and cement, mixed in the proportions hereafter specified Whenever the amount of work is sufficient to justify it, approved mixing machines shall be used. The ingredients shall be placed in the machine in a dry state, and in the volumes specified, and be thoroughly mixed, after which clean water shall be added and the mixing continued until the wet mixture is thorough and the mass uniform. No more water shall be used than the concrete will bear without quaking in ramming. The mixing must be done as rapidly as possible and the batch deposited in the work without delay.
>
> "If the mixing is done by hand, the cement and sand shall first be thoroughly mixed dry in the proportions specified. The stone previously drenched with water shall then be deposited on this mixture. Clean water shall be added and the mass be thoroughly mixed and turned over until each stone is covered with mortar, and the batch shall be deposited without delay and thoroughly rammed until all voids are filled. The grades of concrete to be used are as follows: For the arches between skewbacks—1 part Portland cement, 2 parts sand, and 4 parts broken stone, or gravel, that will pass through a 1¼-inch ring; for the foundations, abutments, piers and spandrels—1 part Portland cement, 4 parts sand, and 8 parts broken stone, or gravel, that will pass through a 2-inch ring."

The proportions of 1 : 2 : 4 specified first above for the body the arch proper were used in making the test specimens. Lehigh Portland cement was used the first year and Medusa the second. In the first series of tests hand broken Bedford oolitic limestone was used; in the second the stone was obtained from a crusher at Kankakee, Ill.; the second series also included a bar of the unbroken stone. Local pit gravel of good quality was used; owing to its containing an excess of sand, a ¼-inch screen was used the first year and the coarser material was employed as gravel under the above specifications; in the second season's work, however, it was found by trial that 1 : 5 with the gravel in its natural state was equivalent to the 1 : 2 : 4 proportions screened, and the gravel was no longer screened. The first season's bars were made 6 x 6 x 24 inches, but owing to the great length of time required to heat the 36-square inch section to the center, the second series of bars were made cylindrical, 36 inches long by 4 inches diameter (12.5 square inches, or about one-third the original section).

After finishing the first series it was planned to undertake for the second season's work a somewhat elaborate series of tests including several brands of cement, both Portland and natural, mixed in varying proportions, but in the interval between the two series inquiries as to the first results came from various quarters, chiefly from engineers who were interested in concrete-steel arch construction. It was therefore thought best to withhold the results first obtained until they could be carefully verified, and the second season's tests were directed to the latter end. An attempt was also made to extend the series to include natural cement concretes, but unfortunately the samples of both brands of natural cement tried seemed to have suffered in storage, for their activity was so reduced that the bars broke time and again in attempting to remove them from the mold. Tensile tests of these natural cements gave results which tallied with the behavior of the concrete. It may be stated that a third series is now in preparation which includes not only a variety of qualities of concretes, but also a series of municipal construction materials.

METHOD OF INVESTIGATION.—The general method commonly employed to determine the coefficient of expansion was used, viz.: a bar of concrete of known length was subjected to an observed change of temperature, the increase of length determined, and the coefficient calculated. Previous to undertaking the tests, careful consideration was given to several methods of measuring the increase of length of the bar of concrete. It was at first intended to construct a special micrometer caliper of large size, consisting of a metal bar packed in ice, to secure a fixed length, and having a projecting arm at either end, one for fixed contact and the other to hold the micrometer screw. This plan was abandoned, however, because of anticipated difficulties in securing steady temperatures in both micrometer and concrete bars, and also on account of the doubtful precision of the calibration contact.

In the plan finally adopted a standard bar of steel or copper with known coefficient of expansion was subjected to identical changes of temperature with the test bar of concrete, and the difference of

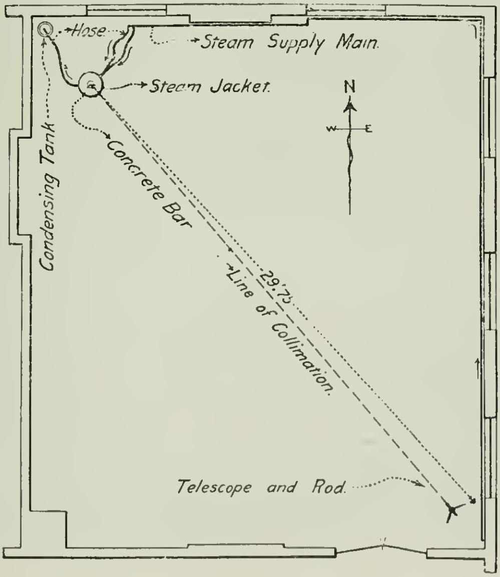


FIG. 1.—Plan of Laboratory.

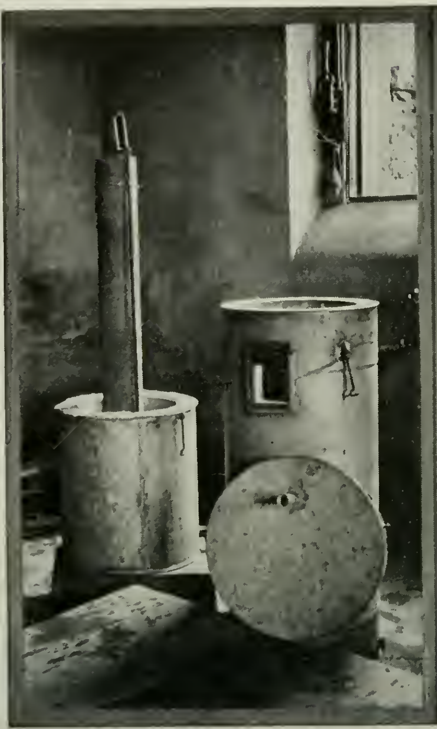


Fig. 2.—Upper Section of Jacket Removed. Test Bar and Optical Lever in Place.

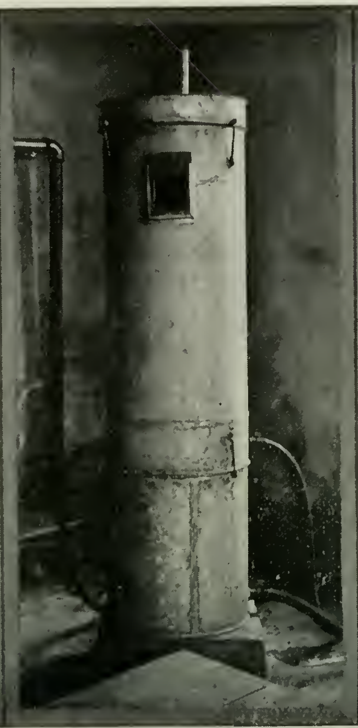


Fig. 3.—Steam Jacket Assembled. Apparatus Ready for a Test.

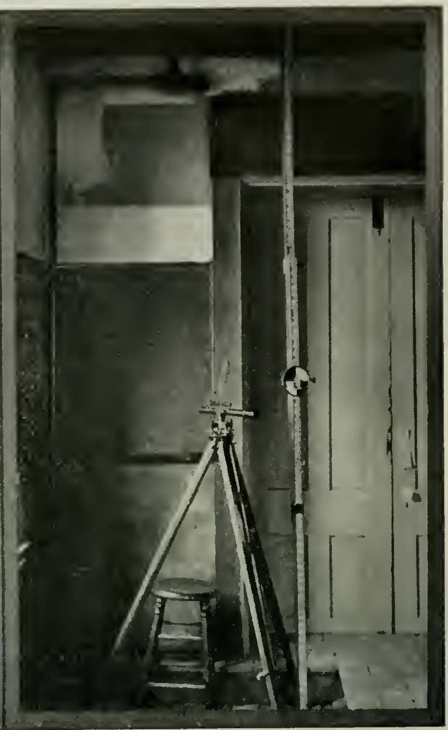
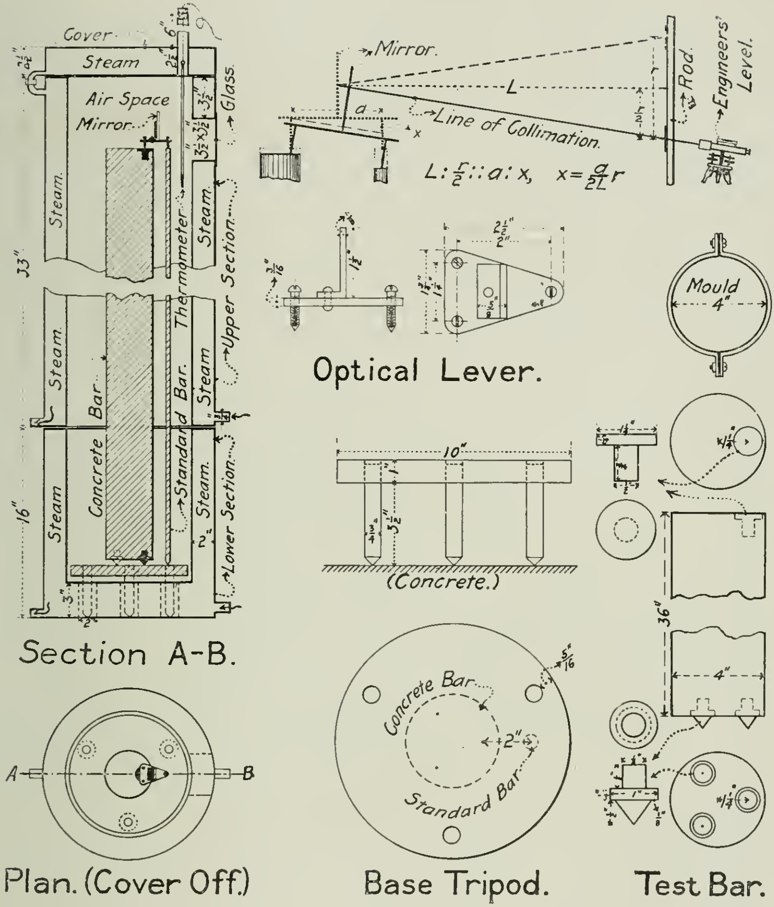


Fig. 4.—Telescope and Rod Used in Tests.



Section A-B. Optical Lever. Plan. (Cover Off.) Base Tripod. Test Bar.

Fig. 5.—Detail of Apparatus.

expansion of the two bars was determined by the principle of the "optical lever." This difference in length, reduced to a unit of length and temperature, gave a correction to be applied to the known coefficient of the metal bar.

Apparatus.—The apparatus in its final form included: (a) Two isolated foundations, on one of which rested the tripod shoes of the engineer's level used by the observer, and on the other a cast-iron tripod base for supporting the experimental bars; (b) a heating apparatus, consisting of a double-walled galvanized iron steam jacket, the inner air space containing the test bars, and communicating with the exterior by means of a square glass-covered window or aperture; (c) the test bar of concrete, supported tripod-like by three conical pointed iron knobs moulded into the lower end, and having a flat disc in the upper end upon which rested one end of the optical lever; (d) the steel or copper calibration bar or rod, pointed below and flat at the upper end to hold the other end of the optical lever; (e) the optical lever, consisting of a small tripod-like metal plate with mirror attached; (f) a standard thermometer suspended within the inner air space; (g) an incandescent electric light to illuminate the thermometer scale; (h) a graduated scale (leveling rod); (i) a telescope (engineer's level).

The steam jacket was lócated in the opposite corner of the room from the telescope and rod, as shown in Fig. 1. The general appearance of the apparatus is shown in the accompanying photographic views. Fig. 2 shows the steam jacket with the upper section and cover removed, exposing to view the concrete bar, with the standard bar held vertically alongside it by means of a wire near the top, and the optical lever in place on the upper ends of the bars. The electric switch seen in the window controlled the current to the incandescent light mentioned above. Fig. 3 shows the jacket assembled ready for a test; the details of the steam jacket, test bars, optical lever, etc., are given in Fig. 5. Fig. 4 shows the arrangement of the telescope and rod, the latter being so placed that the observer could see the target and read the rod himself, while his assistant attended to the apparatus in the opposite corner of the laboratory.

The principle of the optical lever is illustrated in the diagram, Fig. 5. The fixed line of sight (the line of collimation of the level) is directed to the mirror which is so adjusted by the three screws of the plate as to give a reflected reading of the rod standing close beside the observer. Were the bars to expand with perfect equality, the mirror would simply move upward parallel to its first position and the target reading would not change. With an unequal expansion of the bars, however, one end of the lever rises more than the other and the angular movement of the reflected ray is double that of the mirror or lever plate to which it is attached. In these tests it is desired to know the difference in linear expansion of the bars, and not the angular change. This linear difference, x, shown in the diagram, Fig. 5, is found by applying to one-half the target movement, r, the known ratio of the lever arm, a, to the distance from the mirror to the level rod, L. For the sake of simplicity this diagram is drawn as if the initial line were reflected back directly to the observer's eye in the first observation, and with the normal line of the mirror in a horizontal position in the second sighting. With these assumptions the triangles are seen to be rigidly similar, but with the wide contrast in the distances a and L the lines of sight may depart quite materially from these simple relations without affecting the results perceptibly. In these tests the desired distance x was the 1-357th part of the target movement.

To meet the necessity of holding the line of collimation as steady as possible, each tripod shoe of the instrument was surrounded by a batch of neat Portland cement mortar deposited on the concrete base. As a further precaution after the sighting was once established, the adjusting screws of the level tube were changed to bring the bubble precisely in the center; although the radius of curvature of the vial was 115 feet, it was found that the bubble was practically stationary day after day. However, notwithstanding this evident stability of the line of sight, the observer was very careful to avoid disturbing the telescope during a test.

DETAILS OF A TEST.—The progress observed in making a test was as follows: The lower section of the jacket with the legs of the tripod base inserted in the holes was placed on the concrete foundation so that the galvanized iron can did not touch the tripod at any point. The concrete bar was set centrally on the cast-iron base plate with its top plug on the side towards the telescope. The steel or copper calibration rod was then wired in a vertical position alongside the concrete bar and the mirror tripod or lever was set in place on top of the bars, as shown in the photograph, Fig 2, and in the vertical section and plan of the assembled apparatus, Fig. 5. The mirror was adjusted roughly to bring the level rod into view, requiring a slight lateral reflection, as indicated in the general plan, Fig. 1; after which the upper section of the steam jacket was set in place on the lower, with an asbestos gasket between the two. A similar gasket was placed above, and an incandescent burner was suspended by means of its wire cord near the top of the air space. The jacket cover was then attached to the upper section by means of a swivel pipe coupling, so arranged that the cover could be swung aside to give ready access to the inner space as desired. The thermometer was inserted through the tube in the cover, its height being adjustable by means of the suspending cord passing through a cork in the top of the tube, so that the position of the mercury could be read with the telescope through the square aperture or window in front of the jacket. The mirror was then given a more refined adjustment so as to show a clearer view of the rod, after which the glass window slide was closed and the apparatus was allowed to stand over night to permit the two bars to assume identical temperatures.

In the earliest tests of the first season an effort was made to gain a wider range of temperature by cooling the jacket with ice water, but this plan was abandoned partly on account of leakage and also because atmospheric moisture condensed on the glass over the jacket window so as to prevent a clear vision in the reflected image of the target. It was found, however, that a lower initial temperature could be produced in the test bars by cooling off the laboratory over night. This was done by shutting off the steam heat and opening the windows for a time.

The test was usually started early in the morning. The observer, seated on a stool behind the telescope, noted the position of the bubble, set the target carefully by reflected vision, and read the thermometer, the electric current being turned on for only an instant so as to avoid affecting the temperature of the air space. After repeating the initial observations as a check and recording the readings, steam was turned on; first draining out the condensed steam from the supply main. The hose was attached, one length to the lower and another to the upper section of the jacket, as shown in Figs 2, 3 and 5. The outlet pipes were run into the condensing pail or tank in the corner of the room, Fig. 1. The steam supply was turned on gradually, and simultaneous readings of the rod and thermometer were then taken at intervals of 15 minutes or so until the target and mercury became stationary. This usually required from 5 to 6 hours, and the observations were continued for an hour or so longer to make sure that the concrete bar was heated to the center. As the temperature of the air space increased the metal bar responded quickly, but the concrete bar expanded very slowly owing to the time required for the heat to penetrate its mass. This was clearly indicated by the rapid change in the target settings within the first hour, a maximum change of more than

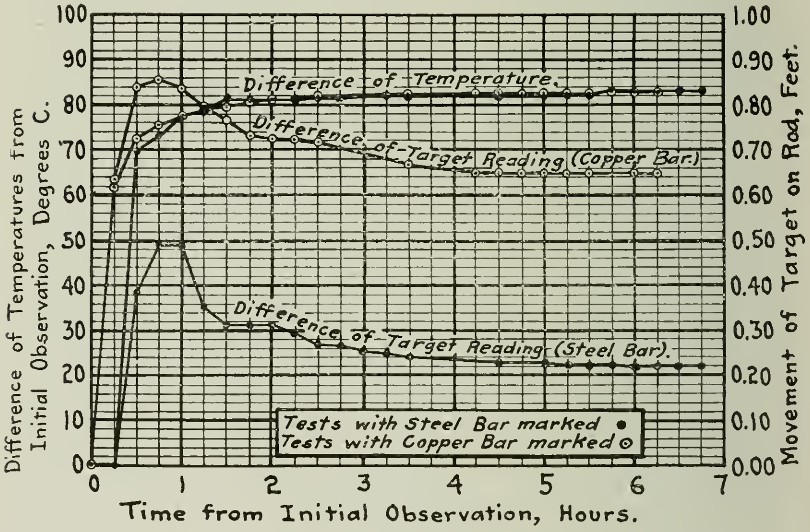


Fig. 6.—Typical Expansion Diagram of Concrete Bar.

0.8 foot occurring with the copper bar in say 45 minutes, and 0.5 foot or so with the steel bar in about the same interval of time. After passing this peak the rod differences gradually declined, due to the other end of the optical lever rising as the concrete bar expanded. These phenomena are clearly shown in Fig. 6 which is a typical diagram of temperature and rod differences for the tests of a bar of crushed stone concrete with both steel and copper standard bars. A casual examination of this diagram with its fairly smooth curves might, perhaps, lead one to think that the apparatus lacked delicacy, but the extreme sensitiveness of the optical device was clearly shown during the first year's tests when a small improvised boiler was used to supply steam to the jacket, a very slight reduction in the steam supply causing an immediate and marked drop in the rod reading, This was also observed on more than one occasion in the second series when the steam supply was cut off temporarily from the laboratory. However, the normal curve was quickly resumed when the steam was again supplied with full pressure. The final basis for the conclusion of an experiment was the sustained equality of mercury and target readings, the observations agreeing to the nearest 0.1 degree Centigrade and 0.001 foot, respectively.

Reduction of Data.—During the first year's tests only one calibration or standard bar, a $\frac{5}{16}$-inch steel rod, was used, and the results were originally reduced with reference to an assumed value of the coefficient of expansion for that metal. However, at the beginning of the second season's tests, the coefficient of expansion of the steel bar was determined experimentally, as was that of a copper rod which it was thought best to use in the tests for the purpose of verification. Acknowledgment is made of the co-operation of the department of Physics of Purdue University both in determining these constants and in suggestions relating to the apparatus used in the experiments. The results of each set of experiments was consistent within itself, but the two sets were at first discordant as compared with each other. However, this discrepancy disappeared upon again reducing the first series with reference to the coefficient of expansion of the steel bar as determined experimentally.

The length of the standard metal bar was made such as to bring its top about on a level with the concrete bar when resting on its three supporting knobs. As the concrete bars were moulded from 0.01 to 0.03 foot longer than the 3.00 feet originally planned for the second season's bars, it was necessary to make the calibration bars about 3.07 feet in length. In the data it was assumed that the computed distance x, Fig. 5, represented the difference of expansion for a length just equal to that of the concrete bar proper. It is believed, that this assumption is consistent with the degree of refinement maintained in reading the temperatures and also with the number of decimal places preserved in the final results given below.

Results of Tests.—Each series included ten tests, of which five of the earlier and three of the later series were rejected because of obvious defects in the apparatus or for other sufficient cause. Of the five successful tests of the first series, four were on broken stone concrete bars and one on a bar of gravel concrete; and of the seven acceptable results in the later series, three were of gravel concrete, three of broken stone concrete, and one of a bar of the unbroken stone from the same quarry at Kankakee, Ill. The final results were as follows:

Table I.

COEFFICIENT OF EXPANSION OF 1:2:4 BROKEN STONE (PORTLAND) CONCRETE.

Series	Test	Kind of Stone	Brand of Cement	Standard Bar	Coefficient of Expansion (Fahr.)
First	No. 5	Bedford	Lehigh	Steel	0.00000 52
First	No. 6	Bedford	Lehigh	Steel	0.00000 53
First	No. 7	Bedford	Lehigh	Steel	0.00000 53
First	No. 10	Bedford	Lehigh	Steel	0.00000 57
Average of results of first series					0.00000 54
Second	No. 2	Kankakee	Medusa	Steel	0.00000 56
Second	No. 3	Kankakee	Medusa	Copper	0.00000 54
Second	No. 8	Kankakee	Medusa	Steel	0.00000 57
Average of results of second series					0.00000 56
Average of entire series of results on broken stone concrete					0.00000 55
Coefficient of expansion of Kankakee limestone bar					0.00000 56

Table II.

COEFFICIENT OF EXPANSION OF 1:2:4 (OR 1:5) GRAVEL (PORTLAND) CONCRETE.

Series	Test	Proportions	Brand of Cement	Standard Bar	Coefficient of Expansion (Fahs.)
First	No. 4	1:2:4	Lehigh	Steel	0.00000 54
Second	No. 4	1:5	Medusa	Steel	0.00000 55
Second	No. 7	1:5	Medusa	Copper	0.00000 53
Second	No. 10	1:5	Medusa	Steel	0.00000 52
Average of results of second series					0.00000 53
Average of entire series of results on gravel concrete					0.00000 54

Grouping results still closer, we have for these experiments:

Coefficient of expansion of gravel concrete, 0.00000 54 per degree F.

Coefficient of expansion of broken stone concrete 0.00000 55 per degree F.

Coefficient of expansion of linestome bar, 0.00000 56 per degree F.

These results confirm the very natural supposition that the coefficient of expansion of broken stone concrete is not essentially different from that of the solid ledge from which the aggregate was crushed. This conclusion accords with the theory of an ideal concrete, in which the mortar exists in a thin film enveloping each fragment of the aggregate. It was intended to determine the coefficient of expansion of a bar made of 1:2 Portland cement mortar in the second series, but this test was inadvertently omitted. Considering the nature of the materials used in the manufacture of cement, however, it is more than likely that the result with such a bar would not differ greatly from those above summarized.

In conclusion, it may be said that while the scope of the experiments described in this paper is not such as to warrant a final judgment, still the results are believed to justify the tentative conclusion that *the coefficient of expansion of concrete is about 0.00000 55 per degree Fahrenheit.* (This value is conveniently remembered as "five zeros fifty-five.")

DISCUSSION.

Mr. Geo. S. Morison, New York City (by letter)—I have read with great interest Prof. Pence's paper on "The Coefficient of Expansion of Concrete," and I wish I could be present at the meeting at which it is to be discussed. It bears out what I have long believed to be the case, that when metal is so placed inside of concrete, and perhaps other kinds of masonry, that it can only receive changes of temperature through the concrete itself, the two can be depended on to work together so far as temperature is concerned. The conditions would be very different if heat could get to the steel in any other way than through the concrete, as for instance, if a pipe was imbedded in the concrete and steam passed through it. The experiments which Prof. Pence has been making are exactly in the line of what I have hoped for years that some one would take up. The method which he has followed has been somewhat unlike what I had contemplated, but perhaps it is quite as good. I have always thought that the concrete member, (the cylinder in this case) should be hollow and the metal rod should be placed inside of it. The advantage of this would be that the high conductor rod would practically always be at the same temperature as the concrete cylinder, and the long time interval required for Prof. Pence's experiments would be very greatly reduced—we may almost say eliminated. The use of the mirror attached to the small tripod which forms the optical level is a beautiful arrangement. The dimensions of this optical lever can, however, be made very small and still have a sufficiently large mirror for all uses required. I see no difficulty in using the same apparatus, even if the metal rod is in the center of the concrete cylinder.

Mr. George Hill, New York City, (by letter)—Referring to the paper by Professor W. D. Pence, "The Coefficient of Expansion of Concrete," I would submit the following:

1st. Scope of Investigation. A considerable experience with steel and concrete in combination, indicate the desirability of testing the combined material for expansion if the results are to have practical value, as concrete certainly acts differently, when combined with metal, in relatively small strands.

2nd. Concrete Bars. It may be that there are a few engineers who still insist that "no more water should be used than concrete will bear without quaking in ramming." For some years I have abandoned this practice and use a very considerable amount of water—I should judge an excess of 15 per cent. Freshly deposited gravel concrete after ramming being so soft that a person walking over it would sink in up to their ankles. This concerte is hard enough in thirty-six hours to run wheelbarrows over it. I am using the concrete in sections ranging from 18 inches down to 4 inches in thickness, and during the past two years have put in place over 50,000 cubic yards, producing in all cases a most excellent concrete. All of my acquaintances who are using concrete in any quantity are following similar practice. Experiments, therefore, made on concrete, mixed with a deficiency of water, are not likely to be of much practical value.

3rd. I have erected concrete walls 700 feet long which have been exposed to temperature changes, ranging from 20 degrees to about 105 degrees Fahrenheit. The only effect of the temperature change that I have been able to discover was the production of three hair cracks too small to admit the introduction of a sheet of paper.

4th. A series of experiments to determine the action of concrete and steel when used in combination, and subjected to cross bending, would have much greater practical value.

Mr. Warren R. Roberts—I would like to ask Prof. Pence one question that may bring out some discussion, viz.: what was the average change in temperature of his tests? Through what variation were most of the tests made?

Prof. Pence—The usual range of temperature in a test was about 60 degrees in Fahrenheit units. Although theoretically the maximum temperature due to the steam heat would be 100 degrees Centigrade, the losses by radiation, etc., were such that the highest temperature noted in the inner air space was several degrees below that of steam.

Mr. Roberts—Do you think that a less variation in temperature would change the results of the tests? You experimented over a great range of temperature many times more than we have in ordinary practice. Would that change the results?

Prof. Pence—I do not know as to that. Our range was usually about the same. There might be some difference in the coefficient, but we do not know as to that. I have not been able to find other consistent values for the coefficient of expansion of concrete. A German authority* (Adie) gives for the coefficient of expansion of stone masonry 0.0000100 per degree C., which is equivalent to 0.00000556 per degree F. This agrees almost exactly with the results of this paper.

The coefficient of expansion of concrete has a two-fold practical interest to the civil engineer; viz.: (1) in connection with the use of steel in combination with concrete, and (2) in the construction of long monoliths of concrete.

It appears to have been a more or less general practice, where attention has been given to the matter at all, to assume that the coefficient of expansion of concrete is identical with that of steel. That this is quite materially away from the truth is easily seen, for taking the usual value for the coefficient of expansion of steel, 0.0000065 per degree F., and the value found in this paper, 0.0000055 per degree F. for concrete, the difference is 0.0000010. That is, the linear change for a given variation of temperature is about 15 per cent. less for concrete than for steel. In the combined construction, where the mortar of the concrete is supposed to adhere firmly to the surface of the steel, it is apparent that this difference in the rates of expansion must produce stress in both materials. When the temperature rises above that of construction the stress in the concrete is tensile, while the reverse is true when the temperature falls below that which prevailed when the mortar of the concrete secured its original grip on the surface of the steel. Since the critical stress in concrete is tensile—in fact, the steel is designed to reinforce the concrete on the tension side of the beam or arch — we are interested chiefly in the change of temperature which produces a tendency to increase the tension in the concrete. Taking the modulus of elasticity of steel at 30,000,000 and of concrete at 2,000,000 lbs. per squre inch, and assuming that the sectional area of the steel is one per cent. of the section of concrete (from 1 to 1.5 per cent. is the range adopted by good authorities) it is found that the stress in the concrete per degree F. change of temperature, is about one-fourth pound per square inch. Considering the fact that the temperature which prevails during actual construction will in most cases be not much, if any, below the maximum that an exposed structure will be apt to reach in service, it seems quite certain that, in a well designed structure, there are not likely to be induced serious abnormal tensile stresses in the concrete by the cause under consideration. Even with a large drop in temperature, of say as much as 100 degrees, the added compressive stress, (which in this case tends to reduce the tension in the concrete on the lower side) is not large in amount, say 25 lbs. per square inch, which is unimportant.

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*Discussion by Prof. Forchheimer of Aachen, of a paper on the "Design of Impounding Reservoirs," Proc. Inst. Civ. Engrs, Vol. CXV., p. 156 (1894.)

As to the range of temperature to be considered, either in the foregoing connection or with reference to the linear changes in monoliths of concrete, the following figures obtained from the United States Monthly Weather Review are of interest. The localities selected are fairly representative.

TABLE.

RANGE OF TEMPERATURE IN THE UNITED STATES.

LOCALITY.	Range of Temperature. From Mean Summer to Mean Winter.	Degree Fahr. From Max. Monthly Mean to Min. Monthly Mean.
New England	37.7	41.4
Middle Atlantic States	41.9	42.3
West Gulf States	30.7	35.3
Ohio Valley and Tennessee	38.4	42.7
Upper Lake Region	44.7	49.7
Middle Pacific Coast Region	15.8	17.7

The steel rods or bars used in reinforcing the concrete are usually imbedded on the lower or tension face of the beam or arch from 2 to 3 inches deep in the concrete. This depth is approximately equal to the radius of the cylindrical bars of concrete used in the tests described in the paper. The expansion diagram, Fig. 6, indicates that the change of temperature would be transmitted through several inches of concrete in the course of a few hours, so that while it is evident that the concrete serves to delay and equalize the change of temperature somewhat, it can not be regarded as a non-conductor. Some exposed structures doubtless undergo downward changes of temperature practically equal to those of the atmosphere, as indicated by the weather records, and it is likely that with the long sustained low temperature in the colder parts of the country, this is quite generally true of engineering structures. Local conditions, such as the elimination of the sun's heat, exposure to the sweep of cold winds, or the opposite of these, of course produce important modifications. As already suggested, the temperature which prevails during actual construction is usually not far below the maximum that the exposed structure will be subjected to, although this will be modified materially in case the concrete is put in place in freezing weather. Judging alone from the last column of the above table of temperature, the range to be provided for in the colder parts of the United States should be at least 50 degrees, although double this range may be proper in some cases.

The more recent practice in concrete retaining wall construction for track elevation work in Chicago is to provide a distinct joint in the wall every 50 or 60 feet. These joints are tight during construction, that is, in the summer or autumn months of the year, and open up quite distinctly in cold weather. It has been found that with walls of slight cross-section, having a joint every 60 feet, a hair crack has appeared about the middle of each section, tending to show that with small walls a joint should be provided say every 30 feet or so. In long monoliths, then, provision is required for the contraction of the concrete to eliminate or localize tensile stresses in the wall.

Referring again to the combined steel-concrete type of construction, it may be said in conclusion, that the secondary temperature stresses due to the difference of coefficients of expansion of the two materials are not likely to be serious in actual practice, for the following reasons:

(1) The chief range of temperature from that which prevailed at the time the concrete first adhered to the surface of the steel is downward, producing a compressional stress in the concrete section, since the steel contracts more rapidly than the concrete.

(2) The changes of temperature in the structure will be gradual, owing to the fact that concrete is a poor conductor of heat.

In addition to these reasons, it is appropriate to refer to the observations of Considere,* the eminent French authority, who has experimented extensively in reinforced concrete beams.

(3) Reinforced concrete beams will sustain on the tension side, without rupture, a proportionate distortion of from ten to twenty times that at which the simple concrete beam would fail.

(4) Interior stresses are relieved more or less by the slipping of the metal bars in the concrete.

Mr. T. T. Johnston—I feel hardly prepared, Mr. Chairman, to make any connected remarks on this subject, which is certainly very interesting. Prof. Pence's tests have been along the line that will certainly attract a great deal of attention, and doubtless lead to some very useful results.

In observing concretes, one of the things that will engage one's attention particularly will be the changes of volume, that, from one cause or another, may take place in a mass of concrete. There are three principal causes for changes in volume in concrete, judging from the appearance of the concrete:

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*Trans. Am. Soc. C. E. (Aug. 1901) Discussion by Mr. A. L. Johnson, referring to M. Considere's paper in LeGenie Civil, Feb. 4 to 25, 1899.

One would result from what I would conceive to be internal stresses, due perhaps to the quality of the cement used, or possibly to the character of the workmanship put upon the concrete.

Another cause might be due to change in temperature.

Still another cause, which is quite common, is the price the contractor may have received for doing the work.

These three elements certainly work together.

With regard to the manifestation of change of volume due to internal stress,—you may frequently see sidewalks where, in one block, there are cracks through it and in the next block it is all right. The development of the crack from the internal stress may have occurred in conjunction with a slight change of temperature. In other cases we see cracks running parallel to each other across the concrete, and sometimes longitudinally, where I think there is a decided combination of temperature and an initial internal stress in the mass of the concrete due, very likely, to poor workmanship rather than poor cement.

We have quite a number of examples of concrete along the drainage canal, some of which has been in position quite a while. About two weeks ago I had occasion to look some of it over—the concrete walls of what are known as sections 14 and 15 of the drainage canal. The concrete wall in section 14 has a length of about 6,000 feet on each side of the canal continuously. This was built subsequently to the concrete in section 15. Both sections were built under the same specifications. The concrete wall in section 14 is in very bad condition. The top of the wall manifests cracks parallel to each other quite frequently along its length, and there are also a number of longitudinal cracks. In some places the concrete has dropped off into the canal. There, temperature hardly accounts for the condition of the wall; neither do I think the quality of the cement was the cause of the trouble, because it was the same cement as used in section 15, and was tested in the same laboratory by the same methods and with the same results. There are some physical reasons for the condition of that concrete, which I attribute to the workmanship. In the setting up of the concrete these internal stresses must have developed.

Several years ago one of our members, Mr. Harrison, read an interesting paper on the destruction of the natural rock in the bed of the drainage canal from causes aside from temperature. The act of excavation changed the distribution of stress in the mass of the adjacent rock, causing changes of volume very much larger than were accounted for by change of temperature. Similar action may go on in concrete. Passing from Sections 14 and 15 the longitudinal cracks are entirely absent. The transverse cracks going across the top of the wall are not any worse than they were four or five years ago. These are manifestations of temperature changes in the volume of concrete. At the regulating works, where we used a considerable amount of concrete, I find no evidence of bad deterioration at present. Likewise at Joliet, where several years since I put in a large amount of concrete, I do not find cracks to any considerable degree due to changes in temperature, or other causes.

Now, I think in a mass of concrete we find (what has been hinted at by Prof. Pence) that the degree of expansibility and compressibility may play a very important part (as quoted from the Frenchman referred to by Prof. Pence) where the transverse stress is spoken of. There may be a difference in the coefficient of expansion of concrete and the metal, tending to separate them in their direction of expansion, and the condition of stress that might appear in a mass of concrete may be transferred to some other point by the indirect effect of the motion that naturally would be caused by this difference in temperature.

I have observed some pieces of concrete—large blocks—in which there are tendencies toward changes of volume that showed no bad effects after quite a long time. I know of one piece 12 feet square, sustaining a column of water 250 feet high, with a diameter of eight feet, which is free on two of its sides entirely. That mass of concrete has served its purpose very well under a heavy stress, yet sufficiently large to make one anxious as to the development of cracks.

Last fall, about this time, I finished a concrete dam in the state of Idaho, sustaining water 20 feet deep, in which there is no concrete thicker than five feet. The price of cement was high there, and there was every reason to reduce the amount of it in the dam. On this account there would be a reason to look for cracks, but after a year, nothing has been observed.

Just one word as to this much talked of question of what constitutes a dry and wet concrete. I have never seen a statement of the amount of water that should be put into a concrete to make it wet or dry. Several years ago, in connection with tests in the laboratory of the sanitary district, we made some experiments on the degree of plasticity that might be occasioned by the use of a greater or less amount of water. These experiments were hardly extensive enough to draw any conclusions with regard to concrete, but I have a notion that the mortar used in concrete in one case would make a wet concrete, while the identical mortar in another case would make a dry concrete, and I have still further the notion that in a given dry concrete, where there is an abundance of mortar among the stones, a very slight increase of water will make a wet concrete. The difference between wet and dry concrete is very difficult to define and very poorly understood.

Mr. C. D. Hill—Referring to the expansion of concrete, it has been amply demonstrated that there is considerable expansion. In the case of cement sidewalks laid in Chicago, wherever the ends of these sidewalks butt against the concrete curb and gutter it has been observed that the expansion of the sidewalk has broken the concrete curb. This has become so common that the city authorities have instructed contractors not to lay the sidewalk within an inch of the concrete curb. If we apply the coefficient of expansion as demonstrated by Prof. Pence, and assume the length of a block as about 600 feet, with a change of temperature of 50 degrees, there would be an expansion of about 2 inches, and this actually conforms to the observed practice in the city.

Mr. A. V. Powell—Last summer I had occasion to observe the effect of the expansion of concrete, in watching the sea-wall along the Lake Shore Drive. It is a north and south wall and gets the full effect of the sun's heat on it. It is a case where average annual temperatures cannot be applied. That particular wall is 2,900 feet in length.

It is built of artificial stones each of which is 4 feet in length. The stones are placed close together, but not touching each other. After the wall was put in place, the surfaces of some of the stones cracked off. When this surfacing was replaced, it was made continuous, and no attempt was made to preserve the joints between the stones. On examination, I found this resurfacing has separated from the stone, particularly on top, forming elevated ridges at right angles to the line of the wall. My examination was made during the hot weather, when the tempeaature was above 90 degrees. If we apply Professor Pence's coefficient of expansion to a wall of this length, and for a difference in temperature of 100 degrees, (which I do not think is excessive for this particular location) we will find a difference in the length of the wall of 1.7 feet or .7 inches per hundred feet. I found, by measuring the height of some of these elevated portions, that the displacement would be produced by the expansion in 16 feet of wall. As a further evidence that the displacement was caused by expansion, an examination of the wall, recently made, reveals the fact that, since the cold weather, many of these ridges have disappeared, the loosened cement surfacing having dropped back into place.

Mr. Finley—Referring to Mr. Johnston's remarks about the internal stresses being a probable factor in producing cracks in concrete, I would like to ask those who are familiar with the subject if it is not more likely to occur in what is called a wet mixture than in a dry mixture, and if, in the drying out of a mixture of concrete containing a large quantity of water, it would not set up stresses that would develop cracks?

Mr. Johnston—That point, Mr. Finley, I think was very well illustrated by an examination of briquets that were broken at the laboratory of the Alpha cement mills a few years ago. It was noticed they had a variable strength, and they investigated to find out the reasons. They began breaking them one, two, three, etc., days apart after they were taken from the pans. They found that as the first one was broken the whole cross section was wet; in the next one, part of it was wet, and finally the moisture disappeared, and after that they found them breaking even. This is a very good exhibition of what might be expected by having part of it wet and part of it dry, so I can conceive that in a cement with unequal moisture in its body, one part settling earlier than another, internal stresses might be set up from that cause. I have an idea that all concretes have a greater or less initial internal stress in them.

Prof. Pence—Mr. Johnston has quoted a laboratory experiment which seems to throw valuable light on the question of the unsoundness of the cement. I have wondered if, in practice, in the construction of these long stretches of concrete walls, it would not be desirable to get the moist earth backing up against them as soon as possible. The laboratory experiments tend to favor that plan, although I do not know if it is practicable. These laboratory tests were about as follows: A large number of cubes of concrete were stored in a steam-heated laboratory, and it was found that the concrete, instead of progressively gaining strength, lost strength. The mass of concrete lacked the water which was needed to produce crystallization.

Mr. Finley—Prof. Pence read the opinion of a French authority, in regard to the reinforced concrete. Do I understand the experiments referred to were in transverse bending?

Prof. Pence—Chiefly.

Mr. Finley—The fact that it would stand so much more stress in the tension flange would be due somewhat, would it not, to the fact that the neutral axis would be changed?

Prof. Pence—That would have some effect.

Mr. Finley—Then again, if that French authority bases his conclusion on the fact that the cohesion between the steel and concrete has been lessened, I cannot see the great value of the concrete and steel, or how they could work together.

Prof. Pence—Perhaps there is another brief extract that should be read:

"M. Considere subjected an armed beam to a bending giving 20 times the proportionate distortion in the concrete in tension at which it should have failed, and then subjected it to 139 repetitions of loadings, where the proportionate distortion in the concrete ranged from 4½ to 13 times the maximum obtainable from an unarmed piece. He then carefully cut out an annular ring of concrete surrounding one of the rods, and found not only that it was not cracked, but that it was still capable of carrying nearly its maximum load."

Mr. Condron—These conclusions were based, I understand, on the elongation of the concrete; not on its strength. The neutral axis would not enter into consideration there.

Mr. Finley—The elongation was due to transverse bedding.

Mr. Condron—Simply that the concrete is elongated several times more when surrounding steel, than the same concrete would if it were not in connection with steel.

Mr. Finley—I think the statement was that it stood a greater stress. Is it the practice now, in building long walls of concrete to build a solid wall or do they provide for expansion?

Mr. Johnston—The growing practice is to endeavor to equalize the expansion. In dams generally my own notion is that it should be divided into small blocks.

Mr. Powell—I was noticing, to-day, the retaining wall which the Santa Fe railroad has put in near Halsted street, where track elevation is going on. This wall was built of concrete, and is about 12 feet in height. They have divided it into sections of from 50 to 100 feet in length; the partings I should judge to be ⅛ inch. At the surface of the sections, a V-shaped groove is left about 1½ inches in depth. I found on examining these grooves, that they give evidence of a change, since the surfacing was put on, of from 1-32 to 3-32 of an inch. I called the attention of Major Vaughn, who has charge of the work, to this change, and asked it he thought it was due to the change of temperature. His opinion is it was evidence of settlement rather than shrinkage. Apart from the slight change shown at the partings, I did not observe a crack of any kind in the entire surface of the wall.

Mr. Von Oven—In regard to dry and wet concrete, I know of a recent case in which the use of an excess of water in a concrete seemed to have been the probable cause for the development of a number of transverse cracks. The concrete in question, measuring about 15 inches in width and 6 feet in depth, formed the foundation for a shop building 190 feet in length and 42 feet in width. During the construction of this work two different foremen looked after the mixing of the concrete. The one in charge of and completing the first portion of the foundation, namely one side and part of one end, for the building, put in a concrete that was quite dry, but which tamped readily. The foreman completing the balance of the work prevailed in mixing a wet concrete, even after repeated instructions not to make a dry or a wet concrete, but to mix the constituents to an intermediate consistency.

While looking the work over after the concrete had all fully set, I found that four cracks had developed, running transversely to the length of the wall, and in that portion of the work which had been completed with the wet concrete. I then inspected the first part of the work for similar results, which, however, did not exist.

This seems to show that a wet concrete might have something to do with the development of cracks.

Mr. Seddon—A Melan arch is provided with an expansion joint, but most of the arches that I have seen had cracks in them.

In the matter of a concrete dam, I have not had the responsibility yet of building one, and do not know what I would do in that case, but I have the suspicion that, after carefully analyzing the conditions, I would probably build something else.

As I look at it, the difficulty with concrete is not so much its expansion as its contraction. In general it can take up the expansion in compressive strains, but it pulls apart somewhere the first time that its temperature falls very much below the temperature at which it was put in. The case that I have in mind more particularly is that of the conduit for the St. Louis water works extension—about 8 miles of continuous concrete construction—which was altogether put in during the spring and summer seasons, and when cold weather came it simply developed a number of cracks which had to be filled up, as I remember it, with an asphalt mortar. After this they gave no further trouble.

Mr. Sherman—In the line of Mr. Seddon's remarks, in regard to expansion in Melan arches—the JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS of August, 1900, gave an account of some experiments on the rise and fall at the crown of a Melan arch. I computed the stresses under certain conditions that would be caused by the rise and fall that was mentioned by these experiments. This arch was about 65 feet span, 5 feet rise, and 8¾ inches thick at the springing line. A difference in temperature of 1 degree C. caused a movement at the crown of 1 mm. Under the examinations I made, taking the modulus of elasticity of concrete at 1,400,000, and the coefficient of expansion as given by Prof. Pence, a difference of 100 degrees F. caused a stress in tension of 15 lbs. to the square inch. This stress being so light it would not seem that it was necessary to use hinges in the Melan arches, which is a question that has been very much discussed.

Mr. Finley—Returning to the question of wet and dry concrete. I have examined several pieces of concrete construction which our road built some years ago in the vicinity of Chicago, and found quite a number of fine hair-cracks in them, through which I have seen moisture coming, and the thought occurs to me that, as this wet mixture has a certain amount of water in it which in time evaporates, it leaves the concrete porous and permits the seepage of water.

Mr. Johnston—Would it modify your notions any if in one case it is a dry concrete and in the other case wet, the mortar used in either case being identically the same?

Mr. Finley—Not to any great extent. It would still depend on the total amount of water in the concrete. I would still think that the concrete which had the greater proportion of water in it would be the one that would give trouble.

Mr. Johnston—The percentage of water in the mortar would be the same in both cases.

Mr. Finley—But it would not be the same in the concrete.

Mr. Johnston—The mortar itself would quake in walking over it. By adding some more stone it will not quake so much, and adding still more stone it finally becomes a dry concrete.

Mr. Finley—But there you are increasing the volume of the concrete.

Mr. Johnston—The point I was driving at is that the definitions of what constitute a dry and wet concrete are so poor that we become confused when we get to discussing dry and wet concrete. The trouble is, we do not know what it is.

Mr. Finley—I agree with Mr. Johnston that just what constitutes a dry or wet concrete is very poorly defined, and I think the Society should have something definite on that subject. I do not know of anyone more capable of presenting such a paper than Mr. Johnston.

Mr. Chanute—I think Mr. Johnston is probably committed to give us a paper on this subject, and to contribute in the matter I might mention an experience of my own. Some twenty odd years ago, in repairing some stone culverts on the Erie Railway, the stone of which had been injured by frost, we re-lined the culverts with Béton Coignet, made wholly from sand and cement, which we put on in very thin coats, (from three to six inches,) the theory being, of course, that we should put in enough cement to fill the voids between the grains of sand, and enough water to fill the voids between the grains of cement. We found that the water required for that purpose differed very greatly with the fineness to which the cement was ground. We used German Portland Cement. We could not always get the same quality and we had to experiment and to vary the quantities of water which we used. We found that when we had an excess of water, fine hair-cracks developed in those thin coatings which we placed upon the culverts which we lined. As I stated, that lining was thin—from three to six inches in thickness. We also lined a considerable portion of the Bergen tunnel.

Finally the results of our experiments, which lasted two or three years, led us to mix the Béton as dry as possible, so that it came from the mixer looking like ashes and developed a very slight degree of moisture only, after being persistently rammed into the moulds. After that was done it stood perfectly and I believe it has stood to this day.

Mr. Finley—Is it not a fact, as Mr. Morison mentions in his paper, that the difference of the coefficient of expansion in steel and concrete is due to the fact that they do not receive their maximum temperature at the same time. The temperature is transmitted to the steel through the cement and the question is whether the steel is ever subjected to the same degree of temperature as the exposed concrete.

Mr. Liljencrantz—Referring to the proper proportion of water, should not some consideration be given to the time of year in which the concrete is made? If in the beginning of the summer season, the evaporation is, of course, greater; whereas, if made during the early part of the fall there would be a less degree of evaporation and there may be danger of freezing, which might prove injurious.

Mr. Springer—In regard to the time of year in which concrete is put in, I think that in hot weather it is proper to use more water than otherwise, but as a general proposition, in speaking of wet and dry concrete, I should think that it would be reasonable to assume a medium position, not going to either extreme of making the concrete too wet or too dry. Enough water should be used so that none of the particles of sand or cement are unmoistened, then, after mixing thoroughly with the stone, the composition should admit of tamping enough to compress it into a solid mass. All the concrete I have used in this manner has never shown any signs of cracks or failure of any sort.

Mr. Trumbull—These "grooves" to which Mr. Powell refers are the outward indication of joints passing clear through the section of retaining walls, and are of two kinds: First, where the joint occurs between two sections of wall that were put in with an interval of several weeks. In this case the groove shows an appreciable opening. Second, where the adjoining sections of wall or "boxes" were put in, with not more than a day's interval. In the latter case a maximum opening of about 1-32 inch is to be detected. These bulkheads or joints which occur every 60 feet or so in each wall were designed to form lines of weakness in order to control any tendency to crack. They have served their purpose well.

Mr. Tratman—I am inclined to doubt whether steel embedded deeply in concrete has a variation in expansion differing very much from that of the concrete, since it is not directly exposed, and the concrete (which is a poor conductor) acts as an insulating medium and tends to equalize any difference in temperature between the exterior of the concrete and the embedded steel. Thus the maximum changes in outside temperature may never actually reach the steel and the concrete in contact with it. Of course this depends somewhat upon the construction and the location, the most unfavorable conditions being probably reached in the thin crowns of concrete-steel arches. In street railway construction, rails that are embedded in the street paving can be welded at the joints to form continuous bars of steel of very considerable length, and if the work is properly done there will be little evidence of contraction and expansion, the forces being absorbed within the metal and the metal being largely protected from the direct action of temperature changes, although the top of the head is exposed. Continuous rails on ordinary railways, where the whole rail is exposed, have given a good deal more trouble. The matter of the relative changes of temperature of steel members and of the concrete in which they are embedded, under certain changes in atmospheric temperature would be well worth investigation. At present we can only theorize or speculate as to what does or may happen. As to wet and dry concrete, the dryest concrete I ever saw laid was for some street pavement foundations in New York. No amount of ramming could fill the voids, and the finished surface was completely honeycombed with holes, which were eventually filled by the sand for the cushion bed on which the stone blocks were laid.

Mr. Luten—In speaking of wet or dry concrete, I would call attention to an experiment that was described in "Engineering News" some time ago. Two boxes of the same size (I believe they were 3 ft. x 3 ft. x 3 ft.), were balanced on the ends of a beam perhaps 10 or 12 feet long, supported at the middle. One box was then filled with dry concrete carefully rammed; the other box was filled with wet concrete. The two equal volumes of concrete were then permitted to dry for a considerable time. After several months of drying (5 or 6 I believe), the mass which had been placed in the box wet was still the heavier of the two. I am not sure as to all the conditions of the experiment, but it seemed to show very conclusively that the wet concrete was the denser of the two, containing consequently a smaller percentage of voids. It does not follow that the wet concrete would show a greater resistance to crushing, yet the point may be of interest in this discussion.

Another point was brought out by the remarks on the retaining wall which had joints 1½ inches deep on the face. The fact that the wall cracked at those joints seems to indicate that there were not very great local internal stresses at other points. A 1½-inch joint in a 12-foot retaining wall would represent perhaps 1 per cent of its cross sectional area. That the removal of so small an amount of material as 1 per cent could localize the cracking due to contraction from falling temperature, shows that internal stresses arising during the setting of the cement could not in this case at least have been serious.

It has been my experience, in the use of concrete, that where there is danger of cracking due to expansion or contraction, the cracking may in general be prevented by re-enforcing the concrete with steel. Take the retaining wall, for example; if it had been bonded together, from end to end by steel rails embedded and overlapping each other, the retaining wall in all probability would show no cracks at all. I do not believe that the wall would shrink appreciably in length, but that the friction of the earth backing would hold it in place, the elasticity of the materials permitting them to stretch or compress sufficiently to make up for the contraction or expansion; so that one way, perhaps, of preventing concrete from cracking would be to re-enforce it with steel.

In a recent talk with the chief engineer of one of our railroads, I was informed that it was their practice to provide expansion joints in concrete arches perpendicular to the axis of the arch. Thus an arch culvert, having a barrel say 100 feet in length, would be broken into two or three sections 30 to 50 feet in length, to allow the arch to expand or contract in sections, and also to permit local settlement of the arch.

It seems to me, in considering this matter of steel and concrete in combination, that we must admit that the steel will be affected with almost the same variations of temperature as the concrete. Steel imbedded to a depth of one or two feet in concrete and subjected to an external temperature of zero degrees sustained for 48 hours—by no means unusual in winter—would doubtless approach very nearly the temperature of the concrete. But even granting that on account of concrete being a poor conductor of heat, the steel would not be subject to as great variations as the concrete, it would still be possible for the steel at times to have a lower or higher temperature than the surrounding concrete. Assuming that the materials have been cooled to a low point, and that the temperature then rises, the concrete will of course rise in temperature before the steel could be affected. And we might easily have conditions that would cause the steel to have a temperature several degrees lower than the average temperature of the surrounding concrete. Yet the fact remains, that whatever the coefficients of expansion of the two materials taken separately, concrete and steel are being successfully used in combination under the most extreme variations of temperature.

Mr. Bement—There is a subject in this line indirectly in accord with the title of the paper, but one which I think is of much interest as affecting cement; which is the effect of the heat treatment on the material in the rotary kilns, caused by changing temperature owing to irregular condition of combustion. As far as I am aware, no manufacturer has seriously considered the value of a knowledge of the condition of combustion, in the process of manufacture. It is my experience that many of the troubles are caused by irregularity in the burning.

Prof. Pence (closure)—Referring first to the written discussions, the writer concedes that Mr. Morison's suggestion to use a concrete tube with thin walls would be an improvement because of the reduction in the thickness of the mass to be heated. This suggestion will be carried into effect in some future tests, and it is also intended to use two separate optical tripods, one on a steel bar and the other on a copper bar, with simultaneous readings.

Mr. Hill's written discussion of the paper presents several pertinent points which have been quite well covered in the oral discussion. His suggestion at the close that the tests described in the paper would have been more valuable had they been directed to a study of the strength of steel and concrete in combination may be well taken, but the author designedly held close to his text in the paper itself, well knowing that the discussion would tend strongly towards the practical side, as is usually the case in discussing the subject of concrete. It is fair to say, however, that the bars used in these tests were made of fairly wet concrete and hence do not represent extreme practice in either direction.

The writer is glad to note that a number of those who have discussed the paper have taken the trouble previous to the meeting to test the results of the investigation in the light of their actual observations in practice. There are doubtless instances, such as that mentioned by Mr. Powell, where the expansive force of the long concrete mass may cause a lifting of a portion of the structure, usually the top or coping course; but as a general rule, it is the contraction of the concrete wall, rather than the expansion, that is likely to give trouble as was suggested by Mr. Seddon. On this point, I make free to quote a statement by a member after the close of the meeting, to the effect that he has been allowing joints every 60 feet of length for concrete retaining walls for track elevation work; that this practice has seemed to be all right when the wall was of the usual large section; but that with walls having a comparatively slight cross-section, a hair crack has appeared about the middle of the length. This experience has led my informant to believe that it would be better practice to construct the lighter walls in lengths of say 30 feet or so, and it is intended so to do in future work.

Referring to the question of concrete dams, there are obvious reasons in favor of a curved plan to the structure so that the temperature changes merely cause a change in the curvature, as in the arch, thus reducing the probability of rupture.

In conclusion, it might be said that while there are several causes tending to produce internal stresses in concrete constructions, none of these causes is, as a rule, more certain to act than are the temperature changes. Even though the resulting fractures are often insignificant and may offer no serious suggestion of a total failure of the structure, still they constitute a flaw in the work, and are to be avoided if possible.

CXXXVI.

NOTES ON PROTECTION OF METAL WORK OF BALLASTED BRIDGE FLOORS.

By Mr. W. H. Finley.

Presented Nov. 20, 1901.

I have here some samples of another kind of concrete, which differs very much from the kind we have been discussing, for the reason that it will accommodate itself to the expansion and contraction of metal without cracking. This sample represents some asphalt concrete used on a ballasted floor bridge for the prevention of corrosion.

About eight years ago the railroad company I am with, had occasion to put in a bridge in the city of Rockford, Ill. The city insisted that the floor be made water-tight, and I decided to put in a solid ballasted floor, and to protect it by covering the troughs with asphalt mixed with sand in the proportion of about 1 to 1. Recently it was necessary to renew the ties and the gravel ballast that was put in on top of this asphalt, and we took that occasion to make an examination of the asphalt covering. I show here a section of the asphalt concrete, about 2 inches thick, taken out of the bottom of a trough. The California asphalt used did not contain coal tar or any of its products. You will notice, upon examination, that there is considerable life and elasticity to it yet. In fact it is almost as good as on the day it was put in, and the trough from which that was taken was absolutely as dry and well preserved as on the day it was put in.

I thought, in view of the fact that a number of bridges are being erected in this city, which it is necessary to make water-tight, it would be of interest to some of the members to know of our experience with ballasted floor bridges protected with asphalt covering. We have, since the bridge in question was put in, used quite a number of ballasted floor bridges, using pure asphalt only, mixed with sand, and I am satisfied that it is entirely practicable to protect an ordinary ballasted floor bridge so that there will be no deterioration of the iron or steel. This particular bridge has been absolutely water-tight during all these years. It is situated over Main street in Rockford, Ill., and if there was any leakage we would have heard of it very promptly.

I believe all the asphalt compositions used in Chicago contain either coal tar or its products, and in cold weather the concrete cracks and permits the entrance of water between the covering and the iron, with a consequent rapid deterioration of the iron.

I have found, in my experience in applying asphalt to metal bridges, that it was absolutely necessary to have the iron clean as far as grease and dirt are concerned, and that in no case should the iron be damp, cold or chilled. If hot asphalt is put on iron, wood or stone where there is any moisture, it will peel off and will not adhere, so that, in all cases where it has been applied in cold weather, we have had to heat sand and spread it over the iron-work to take out the chill. In summer time the sun is usually hot enough to heat the iron, and artificial heat is not necessary. In one case where we had to take up a subway covering that leaked, we found that it had been applied without first drying off the stone. After the covering was removed, the stone and metal work was cleaned and heated, and a new coating of asphalt put on. We have had no trouble since and it is absolutely water-tight.

The cost is not excessive. I thought I would be prepared to present some figures, but regret to say I am not. Of course after you once make up your mind as to whether you will put in a solid floor bridge or an open floor bridge, the extra cost of this protection is a small amount compared with the total cost. There is no question but that the solid floor bridge costs more than the open floor bridge. I am inclined to think that from now on we will see more solid floor bridges than in the past. Unquestionably there is a great saving in maintenance, on all small structures. They do not require a bridge crew, as the ordinary section man looks after them. You have no trouble from the heaving of the ends as you do in an open floor bridge, and I am satisfied that engineers and those who are responsible for the care and maintenance of railroad structures especially, will give more attention in the future to ballasted floor bridges, and, thinking as I do, I thought these samples would be of interest to members of the society.

DISCUSSION.

Mr. Condron—I would like to ask Mr. Finley if the iron work of those floors was delivered painted?

Mr. Finley—All specifications call for surfaces in contact to be painted in the shop, but I never succeeded in getting an inspector who could prevent the shop men from spreading the paint all over the exposed surfaces.

Mr. Trumbull—I would like to ask if this bridge floor that Mr. Finley speaks of had any drainage or pitch from one side to the other?

Mr. Finley—It was a trough floor and the drainage was pitched from the center of each track toward the sides, and the drainage carried off by troughs.

Mr. Reichmann—How did the asphalt adhere to the iron work?

Mr. Finley—When I visited the bridge they had the greater part of it removed. It was quite difficult to remove, even with a cold chisel.

Prof. Pence—How much pressure was put on in applying it?

Mr. Finley—No pressure whatever, practically. It was put on very much as you would put on any ordinary street paving of asphalt. We first cleaned the iron off as well as we could. We then spread hot sand over the iron to warm it, and then painted over the exposed surfaces with pure California asphalt; then we put in this composition of sand and asphalt and ironed it out with a hot iron.

TECHNOLEXICON.

Mention has been made in the pages of this JOURNAL of the work undertaken by the German Society of Engineers, to publish a dictionary of technical terms in the three languages of German, English and French, under the name of Technolexicon. There has been some correspondence on this subject between Dr. Hubert Jansen, the editor-in-chief of the Technolexicon, and the Western Society of Engineers. Sundry circulars have been prepared and sent out by the German Society of Engineers and Dr. Hubert Jansen, explaining the character of the work contemplated, and inviting the collaboration of other technical societies and of individuals. This has all been noted in the pages of the JOURNAL. Another circular has been received from Dr. Jansen on the "Objects and Plan of the Work," printed herewith, to which the attention of the readers of the JOURNAL is earnestly invited:

OBJECTS AND PLANS OF THE WORK.

As an addendum to the enclosed circular, issued by the Society of German Engineers, I venture to start my editorship of the Technolexicon by a brief description of the objects and needs of such a work and also the essentials in compiling it. (Should any details of the system be changed subsequently—say after the experience of a year's work—all collaborators will at once be informed thereof.)

The main objects of a standard technical dictionary are:

1. Complete vocabulary of expressions (of words and usages).
2. Accurate translation.
3. Universal codification—if necessary creation—of a unified technical language for every country in question.

The *first object* will be attained by conscientious use of the *sources*. Publications issued up to now are the immediate references; international (polyglot) and national (monoglot) technical dictionaries both general and special; all important German, French and English technological textbooks; all large textbooks embracing the basis of mathematics, physics and chemistry; among technical works besides, specifications of patents, technical journals, and lastly pamphlets, treatises, price lists, etc., of the last decades.

To attain completeness, and in a like degree accuracy and reliability, the Society of German Engineers especially reckons (see inclosed circular) on the collaboration of technical societies (industrial and scientific), technical colleges, the more important trades and businesses, trade societies and guilds, as well as the technical authorities and inspectors both at home and abroad.

The more important technical journals can also be of use in the task, for instance (quite apart from their other contents) by abstracting all technical terms from the advertisement pages during some length of time.

What the officials and other servants of these societies, institutes, trades and inspections, each according to his speciality, can collect and note down of technical expressions and practical terms, will form our best source of information from real life.

The technical words and expressions will be taken from:

(a) Correspondence and copying books, circulars, business announcements, newspaper advertisements, price lists, etc., referring to the trades, businesses and institutes,—as far as possible with translation;

(b) The actual conduct of works and institutes, especially the expressions used by foremen and their men; e g., the names of the different parts of a machine, of safety arrangements, of various kinds of screws or the like, of special kinds or important parts of the apparatus (if necessary with a small sketch), of special working processes, of modes of manipulation—in short, the names of every arrangement and contrivance, which have special technical names.

The technical expressions of workmen, which are often very picturesque or to the point, should be specially noted, so far as they are peculiar to the technical language of the industry in question, or are worthy of note—or in other words are suitable for universal adoption.

A note book ("*Merkheft*") provided with three alphabetical indexes which will be of service in entering such words, is enclosed; more copies of it will be sent on application. Everybody who cares to note the technical proceedings either abroad or at home, will use this note book with pleasure and profit. It consists of three divisions, one for each language, each with an index from A to Z.

Every word to be noted should be entered in its proper division according to its initial letter (e. g., all beginning with A . . . under A, without regard to further alphabetical arrangement).

In expressions which consist of several words the most important or catch-word will determine its alphabetical position; and if—as often happens—more than one word can be regarded as the catch-word, they should severally be entered, e. g., "to anneal tiles" under "*a*(nneal" and "*t*(ile."

All German, French or English technical expressions which may crop up in practical work or reading and which are not to be found in the existing dictionaries, should be entered in the corresponding division of the note book, if possible with translation.

The two other divisions are for the alphabetical entering of these translations, and the expressions from the two other languages are of course entered alongside. We beg foremen and workmen to note down *all* technical words and expressions that may occur to them. We have had the note book prepared with good strong paper so as to stand practical technical work.

In this manner the sources which must be tapped for the Technolexicon will soon yield abundantly, if methodically and energetically drawn upon. This way of enrichment must be followed systematically in contrast to most of the technical dictionaries hitherto published, which are mostly re-arrangements of earlier dictionaries, often with comparatively little that is new in them. And even if this source offers much which is already known and noted in previous literature, it will also yield much that is new and valuable.

In accordance with the principles above stated, some of the larger trades, no doubt, have already had a collection made, suitable for the particular trade, of technical words and expressions, with French or English translations. It would be of the greatest assistance to the Technolexicon, or in other words, to technics generally, if a copy of such collections of words could be laid at our disposal for inclusion in the dictionary.

The *second object*, accuracy of translation, can only be arrived at in part by examination of existing literature However good the former dictionaries, etc., may have been, we must on principle consider each individual translation as questionable until confirmed by our collaborators in the different countries. It is this confirmation by many chosen and reliable collaborators that will vouch for the accuracy of each several technical expression.

The *third object*, universal codification—if necessary creation—of a unified technical language, must also be aimed at when producing a standard technical dictionary. Now is the opportunity to clear up and codify technical terms, so that technical language may gain in constancy of expression, the lack of which up to now has been very much deplored.

A universal codification of technical language in the Technolexicon can indeed only be satisfactorily carried out on the following lines:

(a) In each case of dialectical, provincial, antiquated, faulty, etc., usage, in fact of any expression not universally used, reference will be made to the expression in general use instead of putting down a translation; and the expression in general use will be settled by the technical collaborators at home or abroad. Should a universal, everywhere intelligible expression not exist, that expression will be chosen as standard which is most likely to be adopted. If an undisputed adoption is impossible, a practically and linguistically correct expression should be proposed.

(b) In translating any expression into the other two languages, the universal expressions will be given for these other languages, and not provincialisms, rare expressions, etc. If it happens, as in some cases in North America, that there is a different universal expression from that used in England, the American expression would be included as well as the English, with a note such as "*America.*"

(c) To the local, provincial, dialectical, antiquated, rare or faulty expressions one of the following indications or remarks (besides the reference alluded to under a) should be added.:

1. Indication of the locality (town, province, district or country), e. g., *Berlin, Sheffield, Marseille; Lower Rhine, Yorkshire, Limousin; Austria, America, Switzerland;*
2. Indication of the dialect, e. g., *niedersachsisch*, *Kentish*, *provencal;*
3 Indication, whether antiquated;
4. Indication, whether rare, or less used, e. g., *gage*, less used than *gauge;*
5. Indication, whether faulty, or less correct, e. g. *Kohlehydrat*, less correct than *Kohlenhydrat.*

Provincialisms in use, antiquated expressions which are often historically important, and persistent ungrammatical combinations must, however, be included (with a reference to the universal, modern, or correct expression), or else the value of the lexicon would be very much less for those using it in various provinces. Especially the antiquated expressions must not be neglected! For instance, when translating epoch-making works of the past, or even journal extracts, words often crop up which are now superseded, and perhaps the *modern* word may not quite agree with the *old* one (cf. *Secohm—Quadrant—Henry*).

(d) It would very much conduce to a general and international understanding, if small sketches were appended to some words where thought necessary; for great confusion in names often exists in tools, parts of machines, etc. In Germany, for instance, it often happens that these have a different name in almost every province. And when it comes to sifting and arranging the whole of the collected words, there is often no way out of it except by pictorially describing a doubtful word, that is by hieroglyphics. (For a good example of such pictorial explanation, among many other examples, see article: *peen*—["*Hammerbahn*," "*Pinne*"] in Dw. Whitney's '*Century Dictionary*,' 1st Edition [New York 1889-1891], Vol. 4, Page 4357.) Austria and Switzerland have also their dialects, and in no less degree France, Belgium, England and North America.

For the purposes of editing, a very short definition will often be desirable, especially in the case of peculiar, less known or new expressions; and a sketch or small drawing will often materially add to clearness. How far, however, these definitions and drawings will be included in the dictionary, can only be settled after the several articles have been put in shape.

We are convinced that the joint efforts of the Society of German Engineers and the allied societies at home and abroad, the institutes, trades, inspectors, etc., will lead to greater unity in technical nomenclature, by active exchange of opinions between the respective nations, i. e., in this case, their technical representatives both industrial and scientific.

Hereinafter I give some further explanations in addition to the conclusions of the Technolexicon Committee, stated in the enclosed circular of the Society of German Engineers.

Besides the *technical departments* considered in the dictionary, on the one hand mathematics, physics and chemistry, and on the other hand mineralogy, information about timber, drugs, etc., in fact about materials and goods generally, will be included as *auxiliary departments.*

Every expression from these last departments must be included, as every material may become of importance to the technical man, even if it be not so already. Anyhow most of these words will already have been included, as they at the same time belong to some other department (e. g. *lime*, to building materials; *steel*, to metal working, or engine building; *teak*, to ship building, etc.). The knowledge of goods and materials brings us into touch with other departments, too, e. g., mineralogy approaches mining and smelting, dendrology and mineralogy approach chemistry, whilst botany approaches the textile industries, etc.

To completely explain the plan of work roughly sketched in the enclosed circular and the above remarks, I will give the following details as answer to the question: "*What is to be included in the Technolexicon?*"

The following should be included:

1. (a) Naturally *all technical words and expressions* of the several main and auxiliary departments, nouns as well as adjectives, verbs, and adverbs, e. g., *gas; gas motor; gas engine works; equation; acid; carbon; carbonic acid; soluble; crosswise*, etc., etc.

(b) *Names of safety contrivances* for machines, e. g., for drawing engines, etc.

(c) *Names of the diseases of trades* (e. g., *lead poisoning* of compositors, etc., *smoke poisoning* of firemen) and the expressions for accidents in the industrial trades (e. g., the French *rossignol*—spraining of the wrist of the printer's apprentice.

2. All important *technical phrases* from which something useful or important can be learnt, either with regard to technics or grammatical construction.

From a technical point of view all combinations of nouns and verbs (in French and English: verbs and nouns), which are names for a particular technical process, should be included: such as *Ziegel brennen* (—to anneal tiles, or to burn bricks); *Ziegel streichen: ein Nute stossen*, etc., also all other combinations of two or more particles of speech, which together constitute a technical idea (for further information see below under 3 and 4).

With regard to grammar, the best technologist who has possibly had little practice in translation (especially from his own language into a foreign) may find it questionable whether *loslich in* . . . . is in French: *soluble dans* or *en* . . . ., or in English: *soluble in* or *by* . . . . On referring to the Technolexicon his difficulty will be solved at once as there he will find a short suitable example. In short, the Technolexicon will devote its continual attention also to the grammatical regimen of verbs, adjectives and nouns, i e. to the use of the prepositions.

3. Of the greatest importance are the *composite words*, e. g., *gas motor*, etc., as in this respect there is often the greatest difference in mode of expression in the various languages. In English especially, as well as in German, expressions such as the following are common: *cut-and cover-building, cut-and cover-tunnel*, etc.

In previous dictionaries, such expressions, the translation of which is not always at everybody's finger tips, are nearly without exception omitted, e. g., in German dictionaries: *Ab-gas, Abluft, Abwaschprodukte, Fokusdifferenz, Eisenkonstruktionsarbeiten, Tunnelsohle, Tunnelbaukunst*, etc. Such expressions must all be included on principle, quite independent of the fact that they can possibly be translated into French or English only by the use of *de* or *a*, *of* or *for*. For these languages often have a single word instead the German composite word (e. g. *Warmofen*; the English *stove*), or perhaps much shorter expressions (e. g. *Buchsbaumholz-Sagemehl als Streusand*, or shorter perhaps *Buchs*[*baum*]-*Sagsel*, English *box-dust*) or they have the simple or compound words taken or built up from the Greek (e. g. *Warenautomat* or *Verkaufsmaschine*, English *automaton* [colloquially *penny-in-the-slot* (*machine*)]; *Warmekraftlehre* (French *thermodynamique*), or they substitute for our composite words a compound idea (substantive and adjective or the like), such as *Fokusdifferenz: distance focale, focal distance.*

4. Vice versa all *compound ideas* are to be included (such as: adjective and noun, adverb and verb, etc.), as these in a foreign language are often translated by a single word (simple or composite), e. g., English *automatic machine* — German *Automat* or *Verkaufsmaschine;*—German *windschief werden* (of timber, etc) — French *gauchir* or *se dejeter;* German *kreuzweise legen* — French *croiser* — English *to cross* or *to traverse:*

5. In books and treatises a simple word is often used instead of a complex or compound idea, e. g.:

in building:	*Kasten* for *Senkkasten*,
in mining:	*Schild* for *Bohrschild*,
in machinery:	*Stange* for *Kolbenstange;*
so, too, in French:	*tige* for *tige du piston*,
and in English:	*rod* for *piston-rod*, etc.

We beg our collaborators to regularly enter such cases in the note book and to give an indication of the full phrase.

The whole manuscript will be revised before printing so that the necessary references may not be forgotten (e. g.: *Stange* see also *Kolbenstange*).

6. Besides special technical words and expressions, some general technical expressions must be noted, which are used in different departments in the same way, or similarly, or differently, and which often assume a figurative sense even in technical books, e. g.: in German, words such as *Betrieb*, *Forderung*, *Herstellung*, *Leistung*, etc. Similar words, much used and of universal meaning, are in English *action*, *cut*, *supply*, *work*, and in French *coup*, *exploitation*, etc. We shall always welcome translations of such words that are so much used and often ambiguous, as they occur especially in letters, treatises, circulars, etc.

All such words and expressions will be the more useful if the translation is attached; but *even without translation* all communications are of value! Any missing translation will be supplied partly by the editorial staff, and partly by the technical collaborators at home and abroad, and revised many times before printing.

Fancy names (such as *Sanatol*, *Sternolith*) are not to be included, nor expressions formed from a proper name (such as *Brabant-plough*, *Ruchadlo-plough*), which do not present any peculiarity, either technically or in the translation. Especially in the clothing industry such fancy names devoid of interest are numerous, such as "Boa *Livia*," etc.; but even in this trade a lookout must be kept for real technical expressions (e. g. *Ruschen-Boa*, *Feder-Boa*, *Pelz-Boa*), which of course must not be omitted from our dictionary.

The collaborators are begged to enter every notable technical expression they come across in the "*Merkheft*," whether it is or appears ever so familiar; for the omission of seemingly well-known words would cause a distinct gap in the dictionary. N. B. This does not apply to the names of the commonest materials and stuffs such as *wood*, *sand*, *iron*, *water*, etc.; these the editor's staff collate.

As a last request, it is earnestly begged of collaborators to add to all notes for the Technolexicon the special branch and also to give the source of each, whether it is a book, a person, or the collaborator himself who is sending the information. If the source is a book, the page should also be given.

Berlin, March 1901. DR. HUBERT JANSEN.

This whole subject should be of interest to all who are engaged in engineering or technical work, and the readers of this JOURNAL are urged to assist as collaborators in this work. The results of their labors will be of material benefit to themselves, individually, in the first place, and would also be of value to Dr. Jansen and his corps of literary workers. The little blank books mentioned in this circular—and the circulars also—are in the rooms of this Society and are for use.

ABSTRACT—VALUE OF NON-CONDUCTING PIPE COVERINGS.

The preliminary report of comparative tests made on various pipe coverings at the Manhattan Power House, New York, under the direction of George H. Barrus, consulting engineer, are at hand.

The tests were carried out on a scale calculated to give results comparable to actual conditions. The length of time and repetitions should have eliminated errors likely to creep into laboratory trials.

The pipes were arranged for tests with steam at 150 pounds, and at 80 pounds gauge. In the 150 pound section were five 2-inch pipes, 100 feet long and two 10-inch pipes 35 feet long. In the 80 pound section were five 2-inch pipes 100 feet long. Care was taken to secure dry steam by a system of separators and the quality was investigated with calorimeters. The water condensed was collected and weighed on independent scales at the end of each pipe, proper precaution having been taken to avoid loss by vaporization. Uniform conditions of operation were secured for about 7½ hours a day and each specimen from 3 to 30 days. The humidity of the air in the room was observed by wet and dry bulb thermometers and the presence of horizontal draughts was found to be nil by a delicate anemometer. The tests were made for the most part with no current of steam in the pipes, excepting that due to condensation, but to ascertain the comparability with flowing steam, tests were made with steam at a velocity of 18 feet per second and showed no difference in the rate of condensation, this holding true in pipes uncov ered as well as covered. The results reported are here appended, giv ing the condensation per hour for each of the coverings tested:

Coverings on 100 feet of 2-inch pipe 80 pounds pressure.

	Minimum.	Maximum.
John's Asbestocel	13.46	14.07
New York Air Cell	13.88	14.14
Carey's Moulded	14.18	15.00
Johns' Moulded	14.15	15.07
Gast's Ambler Air Cell	14.60	15.14
Bare Pipes	55.75	60.30

Coverings on 100 feet of 2-inch pipe 150 pounds pressure.

	Minimum.	Maximum.
Johns' Asbesto-Sponge Hair Felt 3-ply	10.47	10.93
Johns' Asbesto-Sponge Hair Felt 2-ply	11.21	11.29
Asbesto-Sponge Felted (sectional)	11.20	11.57
K. & M. Magnesia (85 per cent. Carb. of Magnesia)	11.64	12.20
Asbestos Fire Felt (Navy Brand)	13.18	14.00
Bare Pipes.	71.78	72.20

Coverings on 35 feet of 80-inch pipe 150 pounds pressure.

	Minimum.	Maximum.
Johns' Asbesto-Sponge Felted	10.67	11.07
K. & M. Magnesia (85 per cent. Carb. Magnesia)	13.00	13.64
Asbestos Fire Felt (Navy Brand)	14.00	14.64
Watson's Imperial.	15.79	15.93
Bare Pipe	105.90	112.00
Temperature of air of room (Approximate)	50.	75.

P. M. C.

WILLIAM J. YODER.

A MEMOIR.

Friendship, in the presence of a dead friend, remembers his virtues and recalls the acts and deeds which made his good will a prized asset in life's category of things worth having.

To very many in and out of the profession the tidings of the death of William J. Yoder brought a sense of personal loss in which the Western Society of Engineers shares, for he was one of our active and valued members. Born In Mannington, West Virginia, 1865, and dying, in harness, on September 27, 1901, near Tiffin, Ohio in the service of the Baltimore & Ohio Railroad. In the prime of life his usefulness was cut short; as "in the twinkling of an eye" the messenger came to him with none but him to hear the inexorable summons or note the instant in which he yielded obedience.

We learn from one of his earliest associates in the engineering profession, who may be said to have given him his first lessons in the craft to which he gave the after years of his life so faithfully and successfully, that he made his beginning on the West Virginia Central R. R. in 1883 when of lad a 18. In 1886 he followed this early friend, P. R. Harrison, to Illinois, serving underhim as resident engineer in the construction of the Chicago, Madison & Northern R. R. When the writer offered Mr. Harrison the position of division Engineer on that work he wired his acceptance and at the same time asked permission to bring W. J. Yoder with him,and it was, granted. Later observation of his industry and efficiency in the conduct of the work assigned him afforded ample explanation of Mr. Harrison's wish to have one so tried and trusted to help him carry on the work he had undertaken.

In a letter written after learning of our common loss, Mr. Harrison says, "He was always the industrious, loyal, painstaking man, willing to assist his associates, whether above or below him in rank. In his personal and professional life he was above reproach." True words fitly spoken.

His service ended with the C. M. & N. in 1888. In 1888-9 he was engaged in building the Wheeling Bridge & Terminal Railway, Wheeling, West Va.

The JOURNAL of our Society for February, 1897, contains a most interesting and valuable paper descriptive of his work there, read by Mr. Yoder before the Society in January '97.

In 1891-2 he was in the service of the L. S. & M. S. Railway, stationed in Dunkirk, N. Y.

His next service was with the South Park System of Chicago in which he continued for five years. In 1899 he entered the service of the B. & O. R. R. and there ended his life's work.

In 1889 he married Miss May Dunham, daughter of Daniel Dunham of Wayne, Ill. Two sons blessed this happy union, Daniel Dunham, born Aug. 3, 1893, and Richard Arnett, born July 10, 1899. Theirs is the heritage of a good name; what better portion can a father leave? ISHAM RANDOLPH.

JAMES M. HEALEY.

IN MEMORIAM

James M. Healey, a member of the Western Society of Engineers, died Sunday, September 22, 1901, at the residence of his daughter, Mrs. C. L. Smith, in Minneapolis, at the age of 73 years.

Mr. Healey was born near Utica, N. Y., on the 17th of September, 1828, and in June, 1851, entered the service of the Illinois Central Railroad Company, continuing in this service until July, 1892. He was one of the original surveyors of the line and remained as assistant engineer during the construction of the road and after its completion till 1859, when he was appointed division engineer by George B. McClellan (afterwards General McClellan) who was at that time vice-president of the Illinois Central Rlilroad Company. Mr. Healey's division extended from about 50 miles south of Chicago to Cairo, and the construction work and maintenance of way on this division were in his charge as division engineer or roadmaster until 1892, when he resigned the latter position. In addition to the duties pertaining to the work on his division, he was frequently employed on the location and construction of the company's extension of its lines, and on other engineering work off from his division. He was also city engineer for about 20 years of the city of Champaign, where he resided from 1856 to 1896. He became a member of the Western Society of Engineers in October, 1880. As a non-resident of Chicago he was unable to be present regularly at the meetings of the Society, and therefore did not often personally meet the city members, but whenever his other engagements permitted he endeavored to attend the monthly meetings.

Mr. Healey was a most faithful and competent officer of the company he served so long, and commanded the respect and appreciation alike of his fellow officers and of those under his orders. He was himself thoroughly conscientious and painstaking in the discharge of his duties and expected the same faithfulness on the part of his subordinates.

He was universally respected and esteemed by his neighbors and fellow citizens and has left a large number of personal friends who prized him as a warm friend, a model citizen and a genial companion.

L. P. MOREHOUSE,
IRA O. BAKER,
ARTHUR N. TALBOT.

ABSTRACT OF MINUTES OF THE SOCIETY.

Minutes of Regular Meeting No. 457, of Western Society of Engineers, held November 6th, 1901.

The meeting was called to order at 8:30, with B. E. Grant in the Chair.

There were present about 56 members and guests.

The Secretary read the minutes of the previous meeting, held October 2nd, which were approved. He also reported the following as having been elected to membership in the Western Society of Engineers, at a meeting of the Board of Directors held November 5th :

Henry W. Swanitz, Tamora, Ill., Junior.
Robt. F. Wentz, Nazareth, Pa., Active.
J. G. Giaver, 1142 The Rookery, Chicago, Active.
E. E. Amory, R 933, 108 LaSalle street, Chicago, Active.
J. H. Frederickson, 6325 Monroe ave., Chicago, Active.
James F. Case, Manila, Philippine Islands, Active.
J. V. Schaefer, 6630 Yale ave., Chicago, Active.
Richard McCulloch, 2020 State street, Chicago, Active.
Luther V. Rice, 1288 N. Clark street, Chicago, Active.

He also reported the following new applicants, to be acted upon by the Board of Directors at their next meeting :

John M. Sweeney, 1233 Monadnock, Chicago, Active.
Walter T. Curtis, Wilmette, Ill., Active.
Chas. Johnson, 3831 Lake ave., Chicago, Junior.
Lewis W. Riddle, 2535 Indiana, ave., Chicago, Junior.
Howard L. Corthell, 4353 Berkley ave., Chicago, Junior.
Arthur J. T. Bennett, Room 417, 164 Dearborn street, Chicago, Active.
Robt. E. Milligan, 40 W. Quincy street, Chicago, Active.
Wm. J. Wilson, Auckland, N. Z., Active.
W. J. Warder, Jr., 900 Warren ave., Chicago, Junior.

Under the heading of "new business" Mr. G. A. M. Liljencrantz, Chairman of the Entertainment Committee, offered the following :

"Permit me to present a resolution of a vote of thanks to the officials of the C. B. & Q. R. R. for their courtesy in tendering this Society the use of a special train on their road to Streator, LaSalle, Zearing and return to Chicago, on the occasion of our recent excursion on October 5th, 1901.

And also a vote of thanks to Mr. F. W. Matthiessen and Lieut. Geo. P. Blow, the owners and managers of Deer Park, near LaSalle, where lunch was served on this occasion, and which gentlemen did all their power to make the occasion a very enjoyable one."

Seconded by Mr. Hotchkiss, and carried.

There being no other business before the meeting, the Chairman introduced Mr. E. B. Ellicott, City Electrician of Chicago, who presented a paper on "The Protection of Water Pipe from Electrolysis."

This paper was followed by discussion from Messrs. Ellicott, Grant, Chamberlain, McCulloch, Tratman, Kerr, Abbott, Pearce, and Seddon.

Motion to adjourn.

Minutes of Special Meeting, No. 458, of The Western Society of Engineers, held Nov. 20th, 1901, at 8 P. M.:

The meeting was called to order by President Chanute at 8:30 P. M. There were present about 72 members and guests. This being a special meeting there was no business before the Society.

The first paper for the evening was by Prof. W. D. Pence, of Purdue University, on "The Coefficient of Expansion of Concrete." This paper was discussed by Messrs. W. D. Roberts, T. T. Johnston, C. D. Hill, A. V. Powell, W. H. Finley, T. L. Condron, H. W. Von Oven, Jas. A. Seddon, L. K. Sherman, O. Chanute, G. A. M. Liljencrantz, G. B. Springer, M. K. Trumbull, E. E. R. Tratman, D. W. Luten, A. Bement and Prof. Pence.

Written discussions were read by the Secretary from Mr. Geo. S. Morison and Mr Geo. Hill, of New York City.

After discussing Prof. Pence's paper, Mr. W. H. Finley gave a little talk on "The Protection of Metal Work of Ballasted Bridge Floors."

This subject was discussed by Messrs. T. L Condron, H. K. Trumbull, A. Reichmann, Prof. Pence and Mr. Finley.

The meeting adjourned at 10:45.

Minutes of Regular Meeting, No. 459, Western Society of Engineers, held Dec. 4, 1901:

The meeting was called to order by First Vice-President Finley at 8:30 P. M.

There were present about 40 members and guests.

The minutes of the regular meeting of the Sociecty held November 6th, were read and approved.

The Secretary read a report from the Board of Directors, announcing the following list of newly elected members:

John M. Sweeney, 1233 Monadnock, Chicago, Active.
Chas. Johnson, 3831 Lake avenue, Chicago, Junior.
Lewis W. Riddle, 2535 Indiana avenue, Chicago, Junior.
Howard L. Corthell, 4353 Berkley avenue, Chicago, Junior.
A. J. T. Bennett, 417, 164 Dearborn street, Junior.
W. J. Warder, Jr., 900 Warren avenue, Chicago, Junior.

The following list of new applicants was also read:

John A. Fulton, 401 Western Union Building, Chicago, Active.
Wm. H. Beattys, Western Springs, Ill., Junior.
Leonardo Robertaccio, 386 South Halsted street, Chicago.
Wm. J. McAllen, 600 E. Division street, Chicago, Active.
Willard Beahan, Winona, Minn., Active.
Alfred H. Marshall, First National Bank Building, Chicago, Junior.
J. W. Schaub, 1650 Monadnock, Active

There being no further business before the meeting, the papers for the evening were presented. The first one, "A Gas Engine Driven, Direct Pressure, Pumping Plant, with Some Experiments on Pump Valve Area," by Mr. D. W. Mead, had been sent out in advance and was not read at the meeting. As Mr. Mead was not able to be present, Mr. Grant moved that the discussion of the paper be postponed until some future meeting. This motion was seconded and carried.

Mr. Lyman E. Cooley then gave an address on "A Proposed Dam and Water Power on the Mississippi River at Keokuk, Iowa." This was discussed by Messrs. Finley, Snow, Trumbull, Boardman, Rice and Cooley.

The meeting adjourned about 10 P. M.

Minutes of Special Meeting, No. 460, Western Society of Engineers, held December 18th, 1901:

The meeting was called to order at 8:30 P. M. with President Chanute in the Chair.

There were present about 50 members and guests.

This being a special meeting, there was no business to come before the Society, and the reading of papers was at once taken up.

Mr. James Macdonald, M. W. S. E., presented a paper on "Fireproof Grain Elevator Construction," which was illustrated with many lantern slides. The reading of this paper was followed by discussion from Messrs. Chanute, Finley, Condron, Roberts, Bainbridge, Trumbull and Macdonald.

At this juncture the Secretary read a telegram which he had just received from Mr. C. W. Hotchkiss, announcing the death on Tuesday, December 17th, of one of our members, Mr. Benj. Reece, and Mr. T. L. Condron moved that the usual committee be appointed by the President to prepare a suitable memorial. This motion was seconded and carried.

Mr. D. W. Mead gave a short resume of his paper on "A Gas Engine Driven, Direct Pressure, Pumping Plant, with Some Experiments on Pump Valve Area," which had been sent out in advance form to the members and was presented at the regular meeting held on December 4th, the discussion of which was at that time postponed. This paper was discussed by Messrs. Chamberlain, Kerr, Finley and Mead

Meeting adjourned about 10:30.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

Norwich, Conn., Board of Water Commissioners, one pamphlet, "Report on Increasing the Water Supply of the City of Norwich," 1901.

B. F. Sturtevant Co., Boston, one pamphlet, Catalogue No. 117, electric machinery, 1901.

Alfred Noble, Journals of Franklin Institute, 1872-3-4-5-6—54 numbers. One vol.—Geodesia, or the Art of Surveying Made Easy. 1793.

N. W. Harris & Co, Chicago, two volumes, cloth bonnd, "Chicago Securities," 1899-1900.

J H. Warder, Chicago, one cloth bound volume, trade catalogue, McKenzie Furnace Co., Chicago.
One cloth bound volume, trade catalogue, Sulzer-Vogt Machine Co., Louisville, 1894.
20 pamphlets, trade catalogues.

U. S. War Department, one cloth bound volume, "Report, Test of Metals, etc," for 1900.

Geo. P. Loomis, representing Barber Asphalt Paving Co., one pamphlet, "Street Pavements," 1901.

North East Coast Institute of Engineers and Shipbuilders, one volume, half morocco, Transactions Seventeenth Session, 1900-1.

American Institute Mining Engineers, one pamphlet, List of Officers, Members, etc., for 1901.

Prof. C. V. Kerr, Armour Institute, one pamphlet, "Tests of Moffett Roller Bearings in Comparison with Sliding Bearings."

Government, Interstate Commerce Commission, one volume, cloth, 13th annual report, 1899-1900.

Government, Bureau of Steam Engineering, one pamphlet "Annual Report, Chief of Bureau of Steam Engineering," 1901.

Western Cement Co., Louisville, Ky., one pamphlet, "Louisville Hydraulic Cement" 1901.

Institution of Naval Architects, one cloth bound volume, (XLIII) Transactions, 42nd session, 1901.

U. S. Geological Survey, three volumes, cloth, 21st annual report 1899-1900, Parts I and VI.

Edward A. Moseley, Secretary Interstate Commerce Commission, Washington, one volume, cloth, 13th annual report, Statistics of Railways in the United States, 1900.

Geo. S. Morison, New York City, one pamphlet, "Responsibilities of the Educated Engineer," 1901.

Otto Gas Engine Works, one pamphlet, trade catalogue, Gasoline Engines, 1900.

M. F. Collins, Superintendent Lawrence (Mass.) Water Board, one pamphlet annual report for 1900.

League of American Municipalities, one pamphlet, fifth annual report, 1901.

E. A. Birge, Director, Wisconsin Geological and Natural History Survey, one pamphlet, "Clays and Clay Industries of Wisconsin, 1901." Also, "Report on Copper-bearing Rocks of Douglas County, Wisconsin, 1901."

Chicago Library Club, one pamphlet, "List of Serials in Public Libraries of Chicago and Evanston, 1901."

S. F. Patterson, Secretary, Association of Railway Superintendents of Bridges and Buildings, nine pamphlets, "Proceedings Annual Conventions 1891—1900," excepting 1894.

W. M. Camp, one pamphlet, annual report for 1894 of Railway Superintendents of Bridges and Buildings.

American Bridge Co., Engineering Dept., one pamphlet, "General Specifications for Steel Highway Bridges," 1901.

Buda Foundry & Manufacturing Co., Harvey, Ill., one pamphlet, Bogue & Mills System of Railway Gates.

Jos. T. Ryerson & Son, one pamphlet, "'Little Giant' Pneumatic Tools."

Industrial Publication Co., one pamphlet, "How to Become a Good Mechanic.",

National Regulator Company, one pamphlet, "National Automatic Temperature Regulator."

Laufketter-Bendit Mercantile Engineering Co., St. Louis, one pamphlet, "Victor Cooling Towers."

Lake Erie & Western R. R, one cloth bound volume, "Physical Features, etc, Existing January 1st, 1900."

Prof. Herman von Schrenk, St. Louis, one pamphlet, "Fungous Diseases of Forest Trees" (Reprint from Year Book, Department of Agriculture, 1900.)

P. Blakiston's Son & Co., one cloth bound volume, "A Manual of Volumetric Analysis," by Virgil Coblentz.

By purchase—Technological Dictionary in English, German and French, 1891.

Smithsonian Institution, Washington, D. C, one cloth bound volume, Annual Report of Institution to June 30th, 1900.

Secretary Michigan State Board of Health, one cloth bound volume, 28th annual report, June 30th, 1900.

Geo. S. Morison, New York City, five large pamphlets, Reports on "Memphis," "Omaha," "Plattsmouth," "Bismarck" and "Blair Crossing" Bridges,

P. Blackiston's Son & Co., Philadelphia, one cloth bound volume, "Introduction to Chemical Analysis," by E. W. Rockwood, University of Iowa.

Also, one cloth bound volume, "Water and Water Supplies," by J. C. Thresh.

Hugh M. Wilson, of Railway Age Publishing Co., Chicago, one cloth bound volume, "Biographical Directory of Railway Officials of America," 1901. ($3 00.)

One cloth bound volume, "Addresses at the World's Railway Commerce Congress, 1893. Official Report."

One cloth bound volume, "Repairs of Railway Car Equipment, with Prices of Labor and Material," by H. M. Perry, 1899.

Open Court Publishing Co., Chicago, one cloth bound volume, "Geometric Exercises in Paper Folding," by P. S. Row.

The Railroad Gazette, Chicago, one cloth bound volume, "Carbuilders' Dictionary."

Gifford Pinchot, U. S Forester, Washington, D. C., two pamphlets, "Practical Forestry in the Southern Appalacians," by O. W. Price; "Notes on the Red Cedar," by Chas. Mohr.

Spon & Chamberlain,. New York, one cloth bound volume, "Buchanan's Tables of Squares."

E. A. Rossiter, City Hall, Chicago, one volume, half morocco, "Mnnicipal Reports," City of Chicago, 1896.

J. B. Henderson, Hydraulic Engineer, Brisbane, Queensland, Australia, two pamphlets, 13th and 14th Annual Reports of Hydraulic Engineer on Water Supply in Queensland.

By purchase, one volume flexible morocco, "Engineering and Electric Traction Pocket Book," by Dawson, 1901. (Wiley, N. Y.)

By purchase of Engineering Magazine Publishing Co., one cloth bound volume, "The Engineering Index," five years, 1896-1900.

J. H. Warder, Secretary W. S. E., one cloth bound book, (quarto) "Metallurgy of Steel," by H. M. Howe.

DeLaval Steam Turbine Co., New York, one pamphlet, DeLaval Steam Turbines, 1901.

Government, Bureau of Statistics, one pamphlet, Monthly Summary of Commerce and Finance of United States, (October, 1901.)

BOOK NOTES.

Railway Track and Track Work. By E. E. R. Tratman. Revised and enlarged edition, containing additional chapters on "Signals and Interlocking" and "Street Railway Tracks." Cloth, 6x9 inches, 472 pp., 226 illustrations, $3.00.

The publication of the first edition of this book in 1897 marked a distinct era in track work in that its position in the profession of engineering was treated for the first time as a scientific specialty, rather than as one of the subordinate departments involving labor of a more or less skilled character. It was in fact the first "Text Book" on track work and was at once recognized and adopted as such by some of the leading colleges. This edition introduces some valuable new matter, in addition to bringing up to date features that, in the rapid evolution of track work, had fallen a little behind.

Chapter 1—Introduction. Brings out strongly the value to railroad companies of having civil engineers trained to track work as a specialty to deal with the problems involving such enormous outlays and in so doing to draw the proper distinction between what constitutes true "economy" and "cheapness." The hints as to handling requisitions are particularly good. The statistics of Maintenance of Way expenses are well chosen.

Chapter 2—Road Bed Construction. In addition to defining the principles involved, gives numerous illustrations showing the practice of a number of the best roads in the country. Included are sections of road beds in tunnels and some suggestions as to the probable developments of concrete substructures.

Chapter 3—Ballast. Gives descriptions of every form of ballast in use with the most approved methods of handling and delivery and enters in a practical way into comparative cost and efficiency.

Chapter 4—Ties and Tie Plates. When the enormous expenditures for cross ties of the railroads of this country alone are considered, the 30 pages of closely written matter will not appear to be giving this subject undue importance. Valuable information is given as to annual consumption of ties, kinds of timber in use, duration of life in various sections of the country and on a large number of railroads; also methods of estimating annual requirements and the most recent practice in use of preservatives. Tie plates and metal ties are discussed at length.

Chapter 5—Rails. Enters into the evolution of the T form of rail, gives cuts of the various types and discusses the mechanical processes of manufacture, chemical composition, deflections under loads, stresses and expansion spacing.

Chapter 6—Rail Fastenings and Joints. Chapter 7—Switches and Frogs. Chapter 8—Fences and Cattle Guards. Chapter 9—Bridge Floors and Grade Crossing. Chapter 10—Track Signs. Under each heading numerous illustrations of the best devices in use and excellent explanatory matter is given.

Chapter 11—Water and Coaling Stations and other track accessories, treats of tracks and water supply, coaling stations, ash pits, track scales, section buildings, platforms and minor accessories.

Chapter 12—Sidings, Yards and Terminals, deserve especial notice. European as well as American practice is discussed in the arrangement and handling of large yards and terminal facilities.

Chapter 13—Track Tools and Supplies; gives the equipment of section gangs on various roads and detailed description of standard tools for track work.

Under Chapter 14—Signaling and Interlocking—the author without going into details gives the broad general principles governing signaling and interlocking and includes the specifications for signals of the Pennsylvania Lines.

Chapter 16—Street Railway Track, gives some of the detail of construction and maintenance of street railway.

Part Second—Track Work. From chapter 16 to Chapter 27 is discussed the organization of the Maintenance of Way Department, practical methods of track laying and ballasting, drainage and ditching and general rules governing maintenance. The Chapter on Gauge, Grades and Curves describes the methods on many roads of widening gauge on a curve, compensation of grades for curves, use of vertical and transition curves; all details the importance of which were greatly underrated a few years ago in track construction and maintenance, but which are now generally recognized.

The chapter on Switch Work and Turnouts is excellent. Other subjects treated are Bridge and Telegraph Work, Permanent Improvements, Snow, Wrecking, Records, Reports and Accounts. The standards of track construction given in tables I, II and III contain in a concise and useful shape the standards for rail, fastenings, joints, ties, tie plates, ballast, frogs and switches of all the important road in this country.

The book is well indexed and type is clear. The very large number of excellent illustrations si a valuable feature. It is a book which neither the civil engineer who wishes to become a "practical track man" nor the "practical track man" who wishes to become versed in the theory of his profession, can afford to be without. J. S. B.

Mill Building Construction. By H. G. Tyrrell, C. E. Cloth bound; size, 6x9 inches. 42 pp. Illustrated. Price, $1.00. The Engineering News Publishing Co., New York.

Among the new technical books of the present year, I have examined Mr. Tyrrell's "Mill Building Construction." This is a neat volume of 42 pages, fully illustrated with 46 drawings, treating of the subject of "Mill Construction" as a specialty.

The first chapter treats on general features, such as the various loads on roofs and floors, due to dead loads, snow and wind pressure.

The second chapter considers general designs for the construction of walls and roof trusses; lighting and ventilation, and gives a table of approximate prices of material and work.

The third and last chapter is devoted to the consideration of the design of structural details. This considers the various floors commonly used in such buildings, very thoroughly; also the various kinds of roofs, doors, windows, ventilators, etc. The information contained within the book is very compact and handy for reference, making the volume almost indispensable to parties who are interested in mill building construction. F. A. S.

The Inspection and Testing of Hydraulic Cements. Report of Board of Engineer Officers on Testing Hydraulic Cements, with specifications for the several classes used by the Engineer Department. Professional Papers No. 28, Corps of Engineers, U. S. A.

This small volume contains the regulations governing the U. S. Engineers in their work of Testing Hydraulic Cements. It is based on a report made by Major Wm. L. Marshall, Major Smith S. Leach and Captain Spencer Cosby, convened under Special Order No. 56, Headquarters, Corps of Engineers, December 17th, 1900. The report dated June 11th, 1901, was duly approved by the Secretary of War, June 19, 1901, and is now in force.

The report recognizes three grades or classes of cements: American Portland cement, natural cement and Puzzolan cement, or that made from blast furnace slag. Rules are laid down for the sampling of the cement to obtain the quantity for making tests, and also of how these tests shall be made, which govern the question of grinding, specific gravity, activity of hydration, constancy of volume, strength, soundness, etc.

Specifications for American Portland cement, for natural cement and Puzzolan cement are given fully. These, with the regulations previously noted as to testing, would enable any one to know whether he can enter his material in competition with others, in bidding on a supply of cement for government work.

It is to be noted that the tests and requirements are not as severe as some that are issued by engineers in railroad or private practice. This seems to the writer a correct stand, viz,, to ask for a grade and quantity of cement which can be furnished without too great a straining for high results, but which will more likely result in a uniform quality of a good character, then insist upon the cement being tested and meeting these specifications, and finally to use this cement in such proportions and quantities based on its qualities of strength, etc., as will give good sound work. W.

Economics of Road Construction. By H. P. Gillette, C. E. Cloth bound; size, 6x9 inches. 40 pp. The Engineering News Publishing Co, New York. Price; $1.00.

This is a very interesting and instructive brochure on macadam pavements, and is based largely on the author's experience in building macadam roads in the state of New York. There is very little theorizing except such as is based on practical knowledge. The author's theory of the bond or cementation of macadam pavements is undoubtedly correct. Where roads are to be built in the country, considerable economy can be effected by heeding the suggestions as to grading the road. It would have been well to have added a paragraph on the subject of under-draining excessively wet portions of the foundation, and on the prevention of the rise of a mushy foundation through the macadam by means of a layer of sand or similar material.

Of especial value is the detailed statement of the cost of the preparation of the material and of the construction of the pavement. The prices seem high, but are probably correct for the locality where the data were obtained, where small portable crushers are used and local teams cannot haul large loads. In the vicinity of Chicago, crushed stone is produced at one-half the cost, and the cost of hauling is about two-thirds. The author would have done well to have emphasized the necessity and great importance of rolling the macadam pavement thoroughly. At the same time his computations show that he expects an amount of rolling to be done that would be considered very excessive. In Chicago the average steam roller compacts about four times as much macadam as is stated by the author. Again, as to the amount of crushed stone and screenings that can be compacted into a given space. Possibly, as stated by the author, 1.6 cubic yards of stone and macadam can be compacted into 1 cubic yard of finished pavement, provided a 15 ton steam roller is used for a day for each 42 cubic yards of material, but excellent and very durable macadam pavements have been laid where not more than 1.4 cubic yards of crushed stone and screenings were used for each cubic yard of finished pavement, and from 150 to 200 cubic yards of material were compacted each day by the steam roller. It is questionable if there is any economy in doing more than this.

Where there is no other use for the products of the crusher, it is certainly extravagant not to use all of it in the pavement, yet if that portion which will pass over a ½-inch screen and through a 1¼-inch screen can be utilized elsewhere, it is wise to omit it from the pavement, especially from the wearing coat. C. D. H.

Thresh. Water and Water Supplies. By John C. Thresh, D. Sc., (London). Medical Officer of Health to the Essex County Council. Lecturer on Public Health, London Hospital Medical College, etc, 12mo., 527 pages. P. Blakiston's Son & Co., 1012 Walnut St., Philadelphia. $2.00 net.

This is the third edition of an English work first published in the spring of 1896. The work is not written as a general treatise on water supply engineering, but as a popular discussion of the general question of water supply, intending to give "All persons interested in pubtic health the information requisite for forming an opinion as to whether any supply or proposed supply is sufficiently wholesome and abundant, and whether the cost can be considered reasonable."

The third edition contains about 20 per cent more matter than the first and second editions.

The general question of the nature and properties of water are first discussed. This is followed by a discussion of rain water, and the various sources from which water can be obtained, viz., surface water, sub-soil water, natural spring water, deep well waters and river waters.

This discussion is followed by one on the quality of drinking waters; impure water and its effect on health, and the interpretation of water analysis.

Chapters are devoted to the pollution of drinking water and its purification both on a large scale and for domestic supplies; also on the softening of hard water; the selection of sources, and the protection of supplies.

Short chapters are also devoted to the construction of wells, to pumps and pumping machinery, and the storage and distribution of waters.

The English laws relating to public water supplies are discussed in a separate chapter, and some information is given on the construction of the smaller water works systems, and the cost of the same, with a final chapter on water rates in Great Britain.

The work, consisting of some 500 pages is provided with a very good index, and fulfills in an excellent manner the object for which it is written, viz., to give a general knowledge of water works sanitation to the general public. While not purporting to be an engineering work, it contains much of interest to the engineer who may wish to obtain a general knowledge of the subject of which it treats.

D. W. M.

Steam Shovels and Steam Shovel Work. By E. A. Hermann. Published by Engineering News Publishing Co., New York, 1894. 60 pages. 8vo., cloth, $1.00.

Mr. Hermann has gone quite exhaustively into the details of his subject under the various heads—

Steam Shovels:

Which treats of the shovels themselves, giving details of parts as built by various manufacturers.

Steam Shovel Work:

Which treats quite fully of the various classes of work to which the steam shovel is adapted, such as loading ballast, coal, ores, etc., the cutting down of grades in the improvement of gradients of railroads, changing of alignment, etc.

Disposition of Material;

Which goes into the question of the taking of the material from the shovel and wasting it, or placing it in embankments at the point where needed, by various means, such as teams and wagons, cars of various makes and capacities on tracks of standard or narrow gauge, etc.

Cost of Work:

Giving estimates as to what work should cost done in various ways, and also several statements of actual cost.

The work as a whole is, we believe, well written, giving just what the man not experienced in this class of work would want to know, and little could be added, if written to-day, except possibly to state that the use of steam shovels has materially increased since the writing of this book, and a large number of special shovels for special work constructed. One good feature of the book is the numerous cuts illustrating the makes of the various shovels, and the methods of handling them in a variety of classes of work.

W. S. D.

An Introduction to Chemical Analysis. For Students of Medicine, Pharmacy and Dentistry. By Elbert W. Rockwood, M. A., M. D., University of Iowa. Illustrated. P. Blakiston's Son & Co., 1012 Walnut st., Philadelphia, 1901. Cloth, $1.50 net.

This book is designed to be used as a text book by students of medicine and pharmacy, and the scope of the work is plainly outlined in the preface. The author has been careful to present only such facts and laws as are of interest and value to the average student in the medical college.

Although a knowledge of the elements of chemistry is necessary, before taking up the study of analytical chemistry, the author, in the introduction, discusses briefly various practical chemical operations, such as filtration, evaporation, distillation, etc.

In Part I the tests for the common metals and acid radicals are given, and the usual group methods for the separation of metals and inorganic acids are presented. A number of pages are devoted to the study of the more common organic compounds, including such substances as morphia, strichnia, etc., which are much used by the practitioner. Full directions for making the qualitatixe tests for these substances are given. All those who have had experience in teaching chemistry in medical schools will readily see the great value of this part of the work.

In Part II the subject of quantitative analysis is taken up. The methods given are nearly all volumetric, only a few being gravimetric methods. Here also the author has presented such matter only as is of interest to the medical man.

Part III contains methods, in full, for the sanitary examination of water. Methods for the detection of poisons, both organic and inorganic, are also given; the methods presented are well selected, being the best and most suitable tests for the use of the average student. A short course in blowpipe analysis completes this part.

Part IV contains directions for preparing re-agents for analytical work, giving the formulæ, water of crystallization, grade of purity required, etc.

A table of chemical symbols and atomic weights, and a table of metric weights and measures, conclude the work. L. T.

Geometric Exercises in Paper Folding. By P. Sundara Row. Edited by Prof. W. W. Beman, of the University of Michigan and Prof. D. E. Smith. of Teachers' College, Columbia University, N. Y. The Open Court Publishing Co., Chicago. 5½x8 in. 108 pages and many illustrations. Red cloth and gilt. Price. $1.00 net.

This interesting little book was written some years ago by the Hindoostance, P. Sundara Row, and was intended as a further elaboration of kindergarten work of paper folding, to teach elementary plane geometry. The possibilities of advance work in geometry from the simple folding and refolding of pieces of paper became evident to the author, with the result of this work. Almost any moderately heavy paper can be used, which is preferably cut into squares by the paper dealer before furnishing to the students. It is surprising to one who has studied the geometry of our schools of (say) the last generation, to find what can be accomplished by such simple means as scraps of paper and a knife as a supplement and practical ocular demonstration of the relations between many geometric problems as laid down in the standard textbooks. This work should be of great assistance to the teacher of mathematics.

It will be a surprise to some who might look upon these paper folding exercises as very simple kindergarten work, to learn that the book contains "some well-known problems of ancient and modern geometry," and even has been extended "to show how algebra and trigonometry may be advantageously applied to geometry."

The first nine chapters treat on paper folding to obtain polygons and their relations as treated in the first four books of Euclid.

Arithmetrical, geometrical and harmonic progressions and the summation of series, and the graphic explanation of systems of involution, are shown in the tenth chapter, while Chapter XI treats of regular polygons, and shows how is obtained the arithmetrical value of π. Other following chapters relate to congruence, symmetry and similarity of figures; conic sections and other interesting curves, etc., etc., all based on the fundamental practice of paper folding. W.

Buchanan's Tables of Squares. By E. E. Buchanan. Spon & Chamberlain, New York. 4¼x7¼, cloth bound, 101 pages. Price, $1.00.

This is the ninth edition of this standard book, in which are shown the squares in feet and decimals (to eight places) of all dimensions of feet, inches and sixteenths, from $\frac{1}{16}$ inch to 49 ft. 11 $\frac{15}{16}$ inches, varying by sixteenths. These tables are claimed to be absolutely correct. The book is a useful one, particularly to bridge draughtsmen, as the length of diagonals in bridge trusses can be readily determined. There are many other places of a similar nature, where these tables will be of service in saving some drudgery. The paper and typography are excellent, the figures being very clear and easily read. W.

Cost of Car Repairs. Repairs of Railway Car Equipment, with prices of labor and material. A reference book for railway officials, by H. M. Perry, M.C.B. Chicago, "The Railway Age." 6x8 in., 172 pages. Price, $2.00.

This book is one of those special publications brought out by the necessities of modern railroad service. It is written by a master car builder who has had many years of experience, and who realized the value of such a handbook upon which to base the charges for car repairs. In the railroad service it is necessary to keep a cost-account of all such repairs, and this applies still more to repairs to foreign cars (i. e. cars from off other roads) which expense must be billed back against the railroad company owners of the car repaired. This little manual has the cost of material and labor for all sorts of repairs, to all classes of cars, properly tabulated. By its use the bills for cost of repairs are made uniform all over the country.

Besides these tables of cost of repairs, the book contains a number of other tables of weights and measures, which are of convenience to those using the book.

W.

A Manual of Volumetric Analysis. Treating on the subjects of Indicators, Test-Papers, Alkalimetry, Acidimetry, Analysis by Oxidation and Reduction, Idometry, Assay Processes for Drugs with the Titrimetric Estimation of Alkaloids, Estimation of Phenol, Sugar; Tables of Atomic and Molecular Weights. By Virgil Coblentz, Ph. D., Professor of Chemistry in the New York College of Pharmacy. Illustrated. P. Blakiston's Son & Co., Philadelphia, 1901. Cloth, octavo, 180 pages, Price, $1.25 net.

Volumetric analysis has been so much a part of analytical chemistry that the analyst welcomes any new suggestions or ideas relating to it.

The book before us seems to have been written with the particular end in view to serve the purposes of the pharmaceutical chemist, rather than of the general analyst, and for this reason it will prove a valuable addition to the library of the chemist engaged in general work.

The introduction covers a review of the principles of volumetric analysis and apparatus necessary.

Chapter II is an excellent description of various indicators and their use. This, in fact, is probably the most valuable chapter in the book. Much detail and many examples are given of the preparation of standard solutions, the examples making this part of the work particularly valuable for students. There is nothing new in the chapters on alkalinity and acidimetry, though here, too, there is the same detail which is apparent throughout.

As stated, the chapter on the estimation of alkaloids and pharmaceutical preparations is new in a work of this kind, and valuable for special workers. W. H.

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